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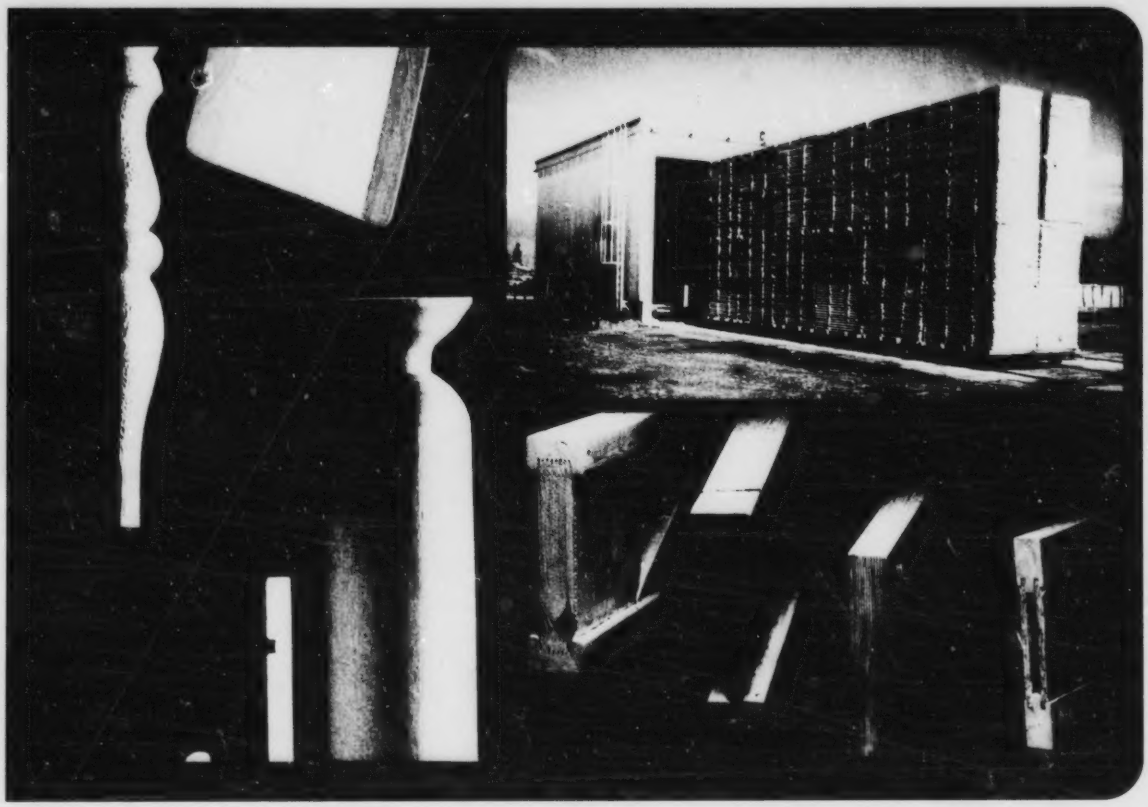

Lumber and Value-Added Wood Products

SPECIAL REPORT

Canada

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TECHNOLOGY ROADMAP

LUMBER AND VALUE-ADDED WOOD PRODUCTS

FORINTEK CANADA CORP.

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FOREWORD

Technology is what has made Canada a world leader in the production and export of wood products. Technology to maximise volume recovery from the available forest resource. Technology to maximise productivity in the mills. Technology to deliver the level of quality expected by consumers. If our industry occupies such a prominent place in the national economy, it is to a very large extent because it has been able to harness technology in its pursuit of customer satisfaction, competitiveness and profitability.

But the world keeps on changing, and so do our technological needs. We need to deal with different resource characteristics, and forest sustainability has become a major social issue. We also need to deal with evolving building techniques and more sophisticated customers who demand affordable products better adapted to their specific applications, not to mention competitors determined to capture a significant share of our residential construction market.

Given our industry's commitment to technology development, and the support provided by governments, we are optimistic that prosperity can be maintained over the foreseeable future. Fast growth in remanufacturing and value-added production, combined with vigorous development in both the appearance and engineered wood product sectors indicate that we are on the right track.

Much needs to be done, however, to provide the Canadian lumber industry and its new value-added sectors with the knowledge, the skills and the equipment it will require over the coming years, and we see this report as a most valuable base on which to build. It relies on a broad combination of scientific, technological, marketing and industrial backgrounds which combine into a strong statement of what is feasible over the ten-year horizon if we seriously set our minds to it.

Industry Canada should be commended for this Technology Roadmap initiative, and we also wish to acknowledge the financial support of Natural Resources Canada (Canadian Forest Service) and the governments of British Columbia, Alberta, Saskatchewan, Ontario, Quebec and New Brunswick. Their commitment confirms a desire to see the wood industry increase its share of global trade through aggressive technological innovation and healthy business development.

This, of course, is only a starting point, an opportunity to take stock of the infrastructure already in place and to create the action plans that will carry us forward. We therefore invite you to review this report carefully, and we trust it will help you develop strategies for your own organisation. We also hope it will encourage you to participate in the follow-up activities that will convert recommendations into action.

Ian de la Roche

Ian de la Roche
President and CEO
Forintek Canada Corp.

EXECUTIVE SUMMARY

Over the past nine years, the Canadian lumber industry has been exporting, on average, over 70 per cent of its production, which makes it a major contributor to the country's trade surplus, and a significant component of Canada's economic success. It also represents a substantial factor in this country's rural economy. Over the same nine-year period, total shipments more than doubled to reach $19.6 billion in 1999. Value-added products only represent a small percentage of this total, but they have experienced tremendous growth, and attracted industry and government attention for their ability to maximise wood product value and exports while creating employment opportunities.

This development results from a unique combination of forest resources and technological innovation giving birth to a variety of products responding to the requirements of major markets, especially in North America, Europe and Japan. As markets become more demanding, global competition more aggressive and distribution systems change (e.g., e-commerce) while traditional wood resources become less abundant, only technological innovation can allow the Canadian lumber industry to maintain and improve its position. This will require new log conversion technology (to extract maximum value from the existing resource on a sustainable basis) and new value-added products and systems (to respond to market needs with smarter solutions).

This Roadmap, developed by Forintek Canada Corp. in consultation with the lumber industry and its major partners, is designed to offer the industry and its stakeholders various technology-related targets to guide its continuing progress over the next 10 to 15 years. It was requested and funded by Industry Canada and by the provincial governments of British Columbia, Alberta, Saskatchewan, Ontario, Quebec and New Brunswick.

In addition to Forintek specialists, consultants, equipment and software producers, the consultative process involved a steering committee representing government partners, and a significant number of representatives from the main sectors of the industry.

The Roadmap establishes the importance of innovation to the softwood and hardwood lumber industry and identifies new and promising technologies along with suggestions on technology development for the future. In addition, it covers two major branches of the secondary manufacturing industry: engineered wood products and appearance wood products. Treated wood products are covered in a separate section. Recommendations are laid out with respect to infrastructure and initiatives that could be included in national, regional or sector action plans, to help the industry to maintain its economic momentum through a stronger competitive position.

The Roadmap is divided into 11 sections which provide a perspective of the entire industry, followed by detailed reviews of the major sectors of the industry: primary manufacturing (softwood and hardwood lumber), and secondary manufacturing / value-added (engineered wood products, appearance wood products and preservative-treated lumber). For each sector, driving forces are set out, which represent major factors shaping the sector's development, and should assist in the selection of the most relevant technologies and recommendations. These may be interrelated and may also encompass other related factors. Corporate requirements for profitability, international competitiveness and market growth, for example, are reflected in the need for cost reduction and new and improved product development. Social preferences and government regulations give rise to environmental requirements. The relative impact of these driving forces varies from one sector to another.

For each industry sector, the information includes a brief description of existing processes and technologies, the identification of key opportunities for incremental technological innovation and, where relevant, opportunities for potentially breakthrough technological innovation.

Incremental technological innovation may take the form of modifications or refinements to existing processes or product characteristics, or it may advance the commercialisation and implementation phases of innovation. This category of innovation is often relatively low-cost and can yield proportionately high benefits without substantial risk. Examples of incremental innovation have been identified that would extend the raw material supply (e.g., innovative applications of aspen, larch, and other under-utilised wood species), reduce production costs (e.g., improved scanning and information management), diversify market applications, and increase profitability through higher product value.

Breakthrough innovation, on the other hand, suggests technological leaps that would significantly affect the economics of the lumber industry. An example might be the systematic introduction of expert systems and totally integrated process control. The research and development (R&D) effort involved to achieve the identified breakthroughs may be heavy, and undoubtedly the risk is high, but so is the potential payoff.

The Canadian lumber industry clearly sees itself evolving towards more remanufacturing, with engineered wood products and appearance wood products being perceived as growth sectors in an industry intent on increasing its client focus as a means of delivering value. Technical innovation is likely to play an even greater role in these fast-evolving sectors, for which market opportunities are extremely varied, and the need for flexibility more critical yet than in the primary sectors. Progress will generally mean increasing attention to, and integration with, clients' manufacturing processes and end-user preferences. Design is singled out as the most potent link between the lumber industry and its new clients, as well as the key to enhanced product value.

The industry's success will depend on choices that are made now, and on the commitment of the industry and its allies to innovation through medium and long term R&D. It will depend on the stakeholders' willingness to support the more fundamental search for knowledge, which so often lays the base for technological innovation. It will also depend on expanding collaboration between the industry, its R&D institutions, its equipment, services and software providers, educational institutions, governments and end-users.

Recommendations are set out as a basis for the development of strategic plans for the Canadian lumber industry. They cover such areas as the acquisition and transfer of technical and scientific knowledge, the setting of priorities for the industry's R&D program, the acquisition of market knowledge, the development of value-added opportunities, and the critical efforts required in training and education. Recommendations apply to all stakeholders including industry, government and research organisations; they are intended to benefit both the lumber industry and its Canadian suppliers.

The Roadmap is written for a broadly-based audience ranging from sector specialists and industry executives to researchers and equipment suppliers to government policy makers and educators. It should not be construed as a comprehensive catalogue of current and potential technology. It is intended, however, to assist organisations in their planning, in setting priorities and in crystallising direction. In addition to providing some guidance on important strategic decisions, it should provoke continuing discussion among the industry's stakeholders. The broad consultation undertaken to develop this Roadmap has already proved very successful in this regard, but it is expected to lead to the development of a living document and specific action plans.

1 Introduction and Overview

Technological innovation has proven to be a major factor in the development of the Canadian wood industry over the past two decades. This trend has accelerated in recent years with the introduction of computer power and the tremendous growth of engineered and other value-added wood products. The challenge for the future is to maintain the pace and to make appropriate choices in setting the direction of technological innovation. It must be consistent with market opportunities and customer requirements. It must ensure optimal benefits to the wood industry and the Canadian economy. It must simultaneously take into account Canadian and international social developments that impinge on the industry's resource, manufacturing processes and markets.

The Roadmap is intended to help the industry meet this challenge. It does not lay out rigid milestones and a single route forward. Suggestions for technological innovation may be applicable to some operations but not to others, and details will need to be fleshed out on a sector-by-sector basis. This Roadmap establishes the importance of innovation to the major sectors in the lumber and value-added industries, identifies new and promising technologies, and provides suggestions on priorities for the future. It also lays out some recommendations related to infrastructure and organisation that may help the various sectors of the industry and their partners to develop specific action plans in order to capitalise on available opportunities.

The Roadmap is written for a broadly-based audience: from sector specialists and industry executives; researchers and equipment suppliers; and government policy makers and educators. It is intended to assist organisations in their planning, in setting priorities and in crystallising direction. Its success will be measured by the debate it provokes and the guidance it provides for important strategic decisions.

Much of the material in the Roadmap comes from Forintek specialists. A series of brainstorming sessions were conducted with the scientists and industrial advisors of both the eastern and western divisions. This was supplemented by discussions with industry and equipment supplier representatives, individual consultants, representatives of educational and R&D institutions, representatives of government agencies, and by a review of the relevant literature.

The consultative process with industry representatives was performed mostly through individual interviews, either in person or by telephone. The industry sectors covered in this Roadmap are: softwood lumber, hardwood lumber, remanufacturing, engineered wood products (excluding panel and panel-based products, which are included in Industry Canada's *Technology Roadmap on Wood-based Panel Products*), appearance wood products, and treated wood products. The scope of the project did not include building systems, but it is recognised that, in a market-driven industry, product development especially in the field of engineered products, can hardly proceed outside a multi-disciplinary systems approach.

In a world of finite resources and growing environmental awareness, technology has to be the ultimate recourse to do more with less. Wood, mankind's oldest building material, and its most environmentally-friendly, remains the popular building choice in many parts of the world. It has even been gaining ground in applications and regions where its use was not traditional. On the other hand, the information revolution and a global trade culture have been challenging traditional products and distribution networks, and competing industries have been investing heavily in development and promotional initiatives to increase their market share.

As the Canadian wood industry reinforces its ability to share the forest resource with other users, and to deliver high-value products meeting modern market requirements, its reliance on technology and knowledge will continue to increase. Efforts to maximise recovery and minimise production costs through improved processes and process control can be expected to continue in the foreseeable future. Market diversification strategies are expected to survive the US quota and short-term incentives, and to support a rapidly expanding value-added sector—with a sector its own appetite for technology and manufacturing innovation, and with a need to expand its design potential.

The Roadmap is divided into nine chapters. Chapter 2 sets the industry in perspective—it looks at its relative economic performance and overall contribution to the Canadian economy. Chapter 3 describes how the industry sees itself developing under favourable circumstances but within practical limits. Driving forces are assessed for the lumber industry, both softwood and hardwood. These are trends and factors that will impact on technological innovation of the near and more distant future. In short, they are the forces which drive technology. One or more driving forces can be related to each technological opportunity, and an understanding of their relative significance also helps in selecting priorities and recommendations.

Chapters 4 and 5 assess the primary softwood and hardwood lumber manufacturing sectors. They focus on technology, describing some of the newer technologies now being used, apparent trends and future technologies. Information in these sections is set out for each stage of manufacture or for important elements affecting the overall manufacturing process, such as process control or by-product utilisation. The information includes a brief description of existing processes and technologies, the identification of key opportunities for incremental technological innovation and, where relevant, opportunities for potentially breakthrough technological innovation. Economic feasibility frequently constitutes an essential element in technology development.

Incremental technological innovation may take the form of modifications or refinements to existing processes or product characteristics, or it may advance the commercialisation and implementation phases of innovation. This category of innovation is often relatively low-cost and can yield proportionately high benefits without substantial risk.

Breakthrough innovation, on the other hand, suggests technological leaps that would significantly affect the economics of the wood industry or individual sectors. The R&D effort involved to achieve the identified breakthroughs may be heavy, and undoubtedly the risk is high, but so is the potential payoff. Chapter 10 describes in greater detail the more promising breakthrough technologies identified in previous chapters. These may apply to all or some of the sectors. They are bold innovations that may well be within reach over the coming decade if sufficient resources are allocated to the pertinent R&D programs. Pursuit of these technologies nevertheless requires close attention to market objectives and economics.

There is clearly a strong link between primary and secondary lumber manufacturing sectors, but the remanufacturing and value-added manufacturing sectors are sufficiently distinct to warrant separate chapters. Chapter 6 covers remanufacturing, while Chapter 7 deals with engineered wood products, Chapter 8 with appearance products, and Chapter 9 with treated wood products. Each of these four chapters provides indications of driving forces specific to these sectors, as well as identifying incremental and breakthrough technologies as applicable.

Recommendations are set out in Chapter 11. As with the major technological breakthroughs described in Chapter 10, recommendations relate to the lumber industry as a whole, with specific sector references as appropriate. The recommendations respond to the goals implicit in the driving forces and the vision statements. They also consider mechanisms that will help bring about the full benefits of technological innovation. Examples include training, technology transfer and co-operation at all levels. Recommendations apply to all stakeholders including industry, government and research organisations, and are intended to benefit both the lumber industry and its Canadian suppliers of equipment and services.

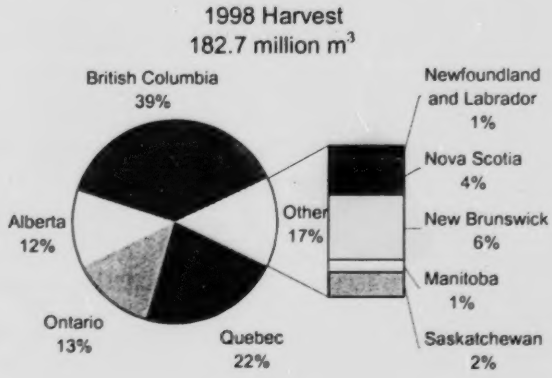
Technological innovation has the potential to revolutionise traditional products and manufacturing processes in the lumber industry, just as it has done in the past. Technology is the vehicle and R&D provides the acceleration to assure the growth and prosperity of the Canadian lumber industry.

The degree of success will depend, however, on choices that are made now and on the commitment of the industry and its allies to innovation through medium- and long-term R&D. In some cases, it will depend on the stakeholders' willingness to support the more fundamental and painstaking search for knowledge, which so often lays the base for technological innovation.

This Roadmap is intended to inspire action plans specifically adapted to the various industry sectors and to specific provincial circumstances. Its many references to Eastern and Western Canada as distinct regions reflect regional differences relating to the resource, traditional industry practices and markets, but many such distinctions are in constant evolution. In many respects, for example, the spruce-pine-fir industry of Alberta may share more common traits with that of Quebec than with coastal BC producers. Regional action plans will undoubtedly capture new similarities and new distinctions.

2 The Lumber Industry in Perspective

The Canadian annual allowable cut in 1997 was 236.6 million m^3 (CFS, 1999). In the same year the harvest for all provinces and territories was 182.7 million m^3 (Figure 1). British Columbia accounted for 39 per cent of the harvest followed by Quebec with 22 per cent. Ontario and Alberta harvested 13 per cent and 12 per cent respectively. New Brunswick and Nova Scotia together account for 10 per cent of Canada's harvest.

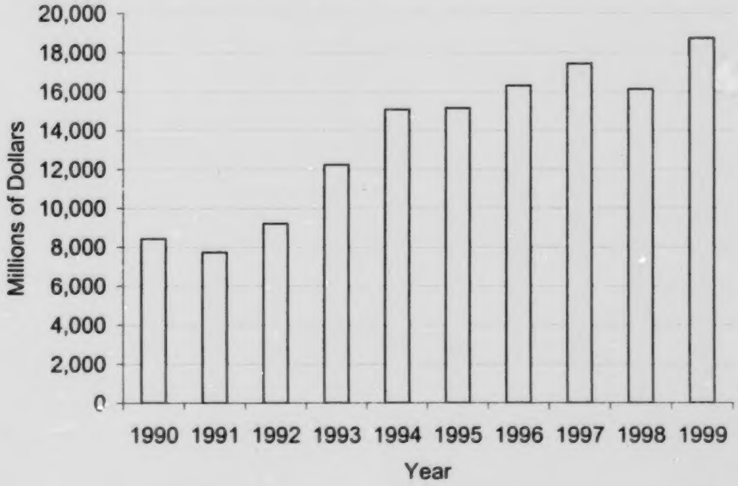


Source: Canadian Forest Service

Figure 1 **Provincial Shares of 1998 Canadian Harvest.**

2.1 Lumber

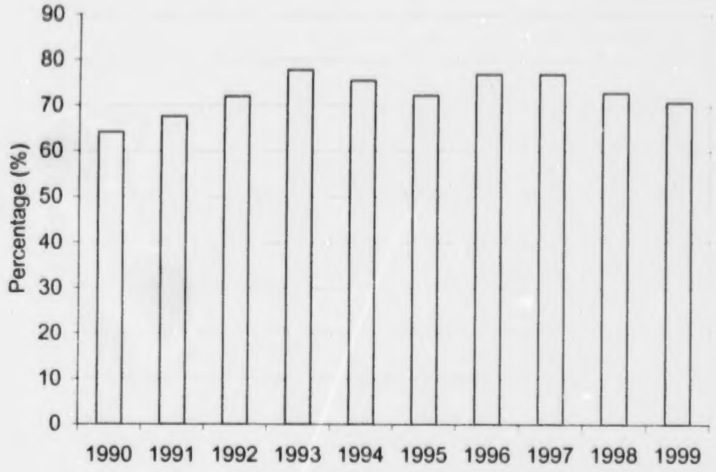
In 1999 the Canadian lumber industry shipped $19.6 billion of product. This accounted for 4.55 per cent of Canadian manufacturing shipments. Figure 2 displays the increase in manufacturing shipments in the 1990s in real dollars. When inflation is accounted for, the increase in manufacturing shipments from 1990 to 1999 is 17 per cent.



Source: Canadian Industry Statistics Development Team/Industry Canada

Figure 2 **Lumber Manufacturing Shipments**

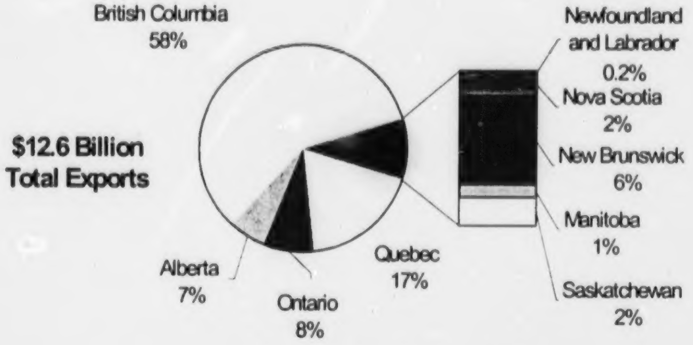
Export markets are very important to the lumber industry. Exports as a percentage of manufacturing shipments were between 64.1 per cent (1990) and 76.9 (1993) per cent with an upward trend (Figure 3).



Source: Canadian Industry Statistics Development Team/Industry Canada

Figure 3 **Exports as a Percentage of Domestic Shipments**

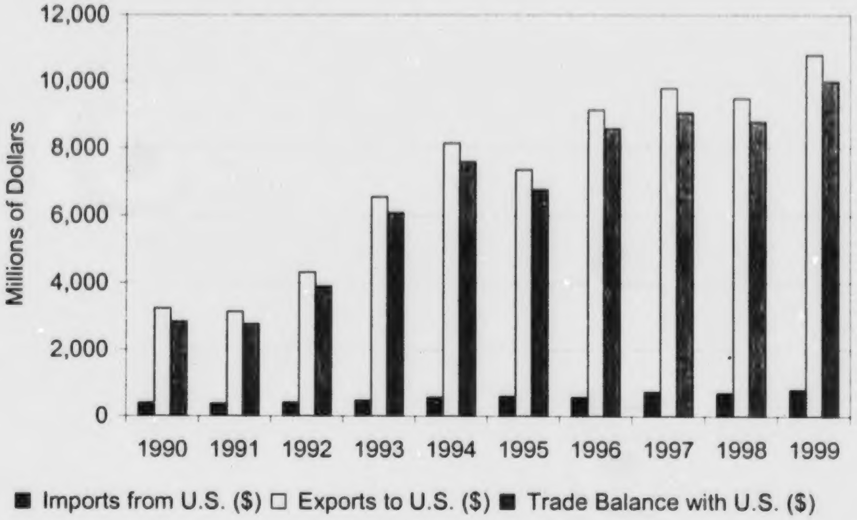
British Columbia and Quebec are the largest exporters of softwood lumber with 58 per cent, and 17 per cent of Canada's 1999 exports respectively (Figure 4). They are followed by Ontario, Alberta and New Brunswick.



Source: Statistics Canada, 2000

Figure 4 **Softwood Lumber Exports by Province, 1999 (Value)**

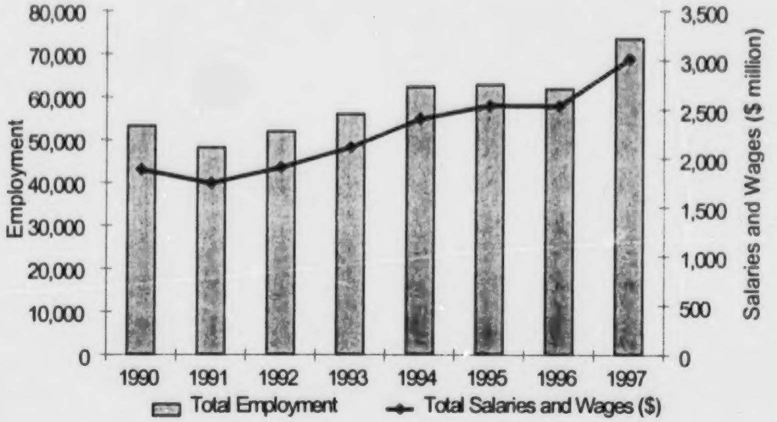
In 1999, over 70 per cent of Canada's export value went to the US. At the same time we imported small volumes of lumber from the US, netting a $10 billion contribution to the balance of trade (Figure 5).



Source: Canadian Industry Statistics Development Team/Industry Canada

Figure 5 **Lumber Trade with the US**

Employment in the lumber industry grew from under 50,000 in 1991 to over 70,000 in 1997 (Figure 6). In the same period salaries and wages earned in the lumber industry grew from $1.7 billion to $3.0 billion.



Source: Canadian Industry Statistics Development Team/Industry Canada

Figure 6 **Employment and Compensation in the Sawmilling Industry**

2.2 Value-added Wood Products

Value-added wood products are a relatively new focus for governments and the industry. There is no set list which defines value-added wood products. Figure 7 displays five categories of value-added wood products accounting for $6.1 billion in manufacturing shipments in 1997.

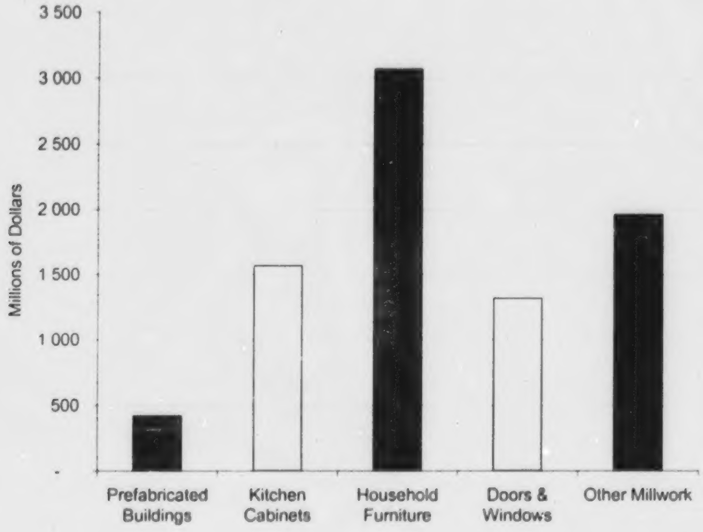
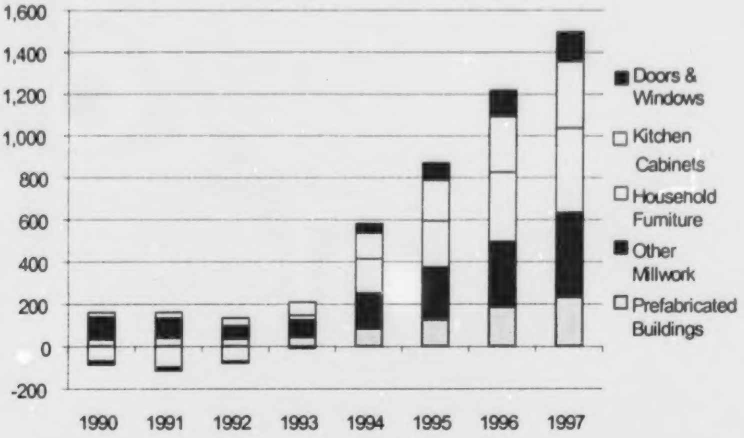


Figure 7 Shipments of Selected Value-added Wood Products, 1997

The contribution of value-added wood products to the balance of trade has increased greatly in recent years. Whereas the balance of trade was near zero for the five product categories in Figure 8 in 1991, it neared $1.5 billion in 1997.



Source: Canadian Industry Statistics Development Team/Industry Canada

Figure 8 Selected Value-added Wood Products Balance of Trade

3 Industry Vision and Driving Forces

Like all businesses, the Canadian lumber business is built on a market, a raw material, and a mass of knowledge that allows the raw material to be turned into marketable products. Much of that knowledge translates into technology. Increasingly, however, the lumber industry's knowledge also relates to market specifics.

In a world of accelerating change, a few things remain constant, and ***the pre-eminence of the US market*** over the Canadian wood industry's horizon is one of them. Whether in commodity production or in value-added sectors, softwood or hardwood, the sheer size and proximity of US consumers will, to a large extent, continue to set priorities for Canadian producers. Irrespective of limitations to free trade, commodity exports to the US will continue to represent a major share of the softwood lumber business, and emphasis on ***cost competitiveness*** will continue. A new factor may be that competition will not be limited to US mills; ***new lumber exporters***, like Chile, New Zealand and some European countries are also exporting to the US market. More seriously perhaps, the North American lumber industry is facing ***expansionist strategies by the steel and concrete industries***, which are determined to gain a larger share of the residential construction market, and to counter wood's initiatives aimed at the non-residential market.

Even if US demand for building materials can be considered relatively permanent, ***end-user expectations and end-users themselves are changing; and so are distribution systems***. The repair and renovation market is now consuming more building products than new residential construction, and ***large, integrated retail chains are in a position to dictate product specifications***. Expanding ***e-commerce*** is expected to have a significant impact within only a few years. The situation is similar for the furniture, flooring and other appearance applications. In this new world, the lumber industry will need to ***maintain an intimate and dynamic knowledge of shifts in demand and in distribution networks***.

Despite its commitment to the US market, and despite recent setbacks in Asia, the Canadian lumber industry will continue to ***develop new markets world-wide*** in the framework of a global economy. This, too, will require market knowledge, cost-effectiveness and flexibility. The US quota has played a major role in convincing even the more commodity-oriented companies that ***customer orientation and flexibility*** are part of the new rules, and that cost-effectiveness, albeit necessary, does not always guarantee profitability.

Market knowledge must extend to ***national and international codes and standards*** that control market access for building materials. In fact, the Canadian lumber industry needs to actively participate in the development of relevant codes and standards, and include such participation in its business plans.

Today's larger commodity companies—and mergers are making them ever larger—will produce an ***increasing variety of grades*** to satisfy their various markets. Many of them will also get involved in ***value-added operations***. Unless such operations are set up as separate businesses, they are likely to deal with high-volume products (e.g., mechanically stress-rated [MSR] lumber, finger-jointed lumber, pre-cut components), and emphasis will be on ***cost-effectiveness and reliability of supply***.

Value-added production, however, will expand the scope of the Canadian lumber industry much beyond past boundaries. ***New players are getting involved***, mostly small and medium companies, and they offer a diversity of products ranging from cut-to-length parts to prefabricated building systems or pre-finished furniture parts. One characteristic of these new players is that they are likely to be ***more closely integrated with their clients' businesses*** than the traditional industry. That means ***better communication*** and full use of fast-evolving information technology. It also means ***technological diversification***.

With respect to the resource supporting the Canadian lumber industry, the main factor bearing on the industry over the coming decade will be that, with a few regional exceptions, ***most of the allowable cut has now been allocated***. As a consequence, any form of growth will have to be based on ***improved utilisation of the existing resource*** and ***process diversification towards value-added products***. For the longer-term, improved utilisation of the resource means improved forest management in order to produce trees better suited to tomorrow's needs, but the results of these efforts will not be felt in any significant way within the ten-year horizon set for the present document. For the short- and medium-term, improved utilisation means ***enhanced knowledge of the available resource,*** including knowledge of ***individual species,*** and measures to ensure that ***log allocation*** allows for maximum value recovery. This will have an impact, not only on the lumber industry, but also on other industry sectors relying on the wood resource, especially the pulp and paper, and wood panel sectors.

Improved utilisation means ***processing logs that may be smaller, shorter, with more natural defects***, and doing it cost-efficiently. It means ***relating the product potential of each log to product specifications*** known to be in demand. It means ***developing the potential of under-utilised resources***, such as non-traditional species or bark. It means ***designing new systems and products*** to do the job—whatever the job may be—with less fibre, and at a lower cost to the end-user, which is another definition of value-added.

Improved utilisation is driven by knowledge, technological knowledge essentially. The development of the Canadian lumber industry over the coming decade will largely rest on ***its ability to take advantage of innovation in the fields of artificial vision and information***. Only by "seeing" product potential in real time in each log, by relating this information to desired product specifications, and by selecting the best technology to match the resource and the product can the industry maximise value yield and minimise conversion cost. Emphasis on scanning and computer power should not be construed as denying the importance of ***machinery development***. As the industry evolves, so does its need for equipment. This is particularly true in the value-added sector, where most advanced machinery is currently imported and does not necessarily respond to local requirements and resources. The Canadian lumber industry should also be in a position to ***trigger innovation*** that serves its objectives.

To be effective, adoption of new technology needs the support *of* ***advanced process development and control***, focusing not only on manufacturing centres but integrating all process parameters that impact on production efficiency, including material flow, handling and maintenance. New technology also needs ***knowledgeable people at all levels in the organisation*** to ensure that management decisions are made on the basis of quality information, that products and processes are designed in the manner best suited to the company's objectives, and that production facilities are operated efficiently not by robots but by people who understand and support company objectives.

Reliance on knowledge and new technology implies a ***commitment to the continual generation and transfer of knowledge*** through R&D organisations, universities and colleges. Managers, engineers and technologists need to be equipped with the basic skills that will let them devise and master new techniques; their ***skills will also have to be constantly updated through training and re-training***. This will require ***technology networks*** involving company personnel, equipment manufacturers, software suppliers, R&D organisations, educational institutions and other service suppliers. The level of technological sophistication envisaged for the Canadian lumber industry will represent a major challenge for many companies; the larger stakeholders have already engaged on the knowledge path, but innovative ways need to be devised to allow smaller companies access to the benefits of high technology.

This overview of factors most likely to impact on the Canadian lumber industry's evolution over the next decade started with comments on market forces and the need for sharp market intelligence. In conclusion, it may be appropriate to come back to market forces, not only to emphasise that only markets confer value, but also to point out that market forces extend far beyond the installed cost of a floor system or the quality of a kitchen cabinet door. As we enter the 21st Century and the age of global information, ***customers' assessment of value takes into account a number of social factors*** that only visionaries considered relevant just a few years ago. In Canada and abroad, customers have their own vision of the lumber industry, as well as their own expectations in terms of ***forest utilisation, environment protection, sustainable development, job creation, impact on local economies***, etc. Value optimisation suggests that the Canadian lumber industry should move towards integrating such values into its plans, and that it should be seen to be doing so.

4 Softwood Lumber Manufacturing – Existing and Future Technology

In Western Canada, the lumber sector has two broad types of sawmills. Coastal mills process large high-grade logs to produce a wide range of specialty products while interior mills use smaller, lower quality logs to produce commodity-type products such as dimension lumber. Softwood sawmills in Alberta are similar to British Columbia (BC) interior mills in terms of raw material supply and product mix. Interior mills focus primarily on North American markets while coastal mills are more diversified; prior to 1996, approximately 65 per cent of coastal production was shipped offshore.

Throughout much of the 1980s, the primary strategy of the western Canadian sawmill sector was to increase revenue by increasing productivity and capacity. Raw material supply was relatively cheap and plentiful, and commodity markets could take as much as the sector could produce. The coast of BC was (and remains) an exception, given the unique size and quality characteristics of the resource; however, productivity was seen to be the key to profitability. There was also a focus on recovery, but again, it was primarily on volume recovery because more lumber volume per unit log volume meant more lumber in the sorter at the end of the shift.

The other important strategy centred on cost reduction, and since mills could do very little about log costs the focus turned to reducing manpower costs. The objective was fewer people producing more lumber. As a result of these strategies, the demands the solid wood industry made on equipment suppliers and systems developers centred on making the equipment run faster, and yield more lumber per unit log volume, and on finding ways to automate what were often very labour-intensive manufacturing processes.

Softwood sawmills located in Eastern Canada operate two or more production lines, usually a small log line and a large (by eastern standards) log line. Small log lines are usually equipped with chipping headrigs that manufacture two- or four-sided cants for breakdown by thin kerf multiple circular resaws. On large log lines the chipping headrigs are often followed by a twin circular or a twin band resaw to reduce cant size before they are directed to the multiple circular resaw.

In Eastern Canada, emphasis has always been placed on mill productivity due to the small diameter of the resource processed. Over the last ten years, however, industry has significantly improved lumber conversion efficiency to counter increasing resource cost and a shortage of raw material. As a result of the implementation of new conversion technologies with sophisticated optimisation capabilities, industry is now able to produce a thousand board feet of lumber with four cubic metres or less instead of the five cubic metres of roundwood it used to require.

Approximately 60 per cent of the softwood lumber volume manufactured in the east comes from small log lines, such as stud lines, that process log lengths between 8 and 10 feet. These production lines are extremely productive and efficient as a result of scanning, log positioning and curve sawing capabilities. In addition, more and more mills salvage short lumber (4 to 6 feet) and have expanded their product mix to include 2" x 2" lumber.

The remaining lumber volume (40 per cent) is produced by large log lines which usually process logs that are 16 feet in length. Log breakdown is normally performed by chipping headrigs followed by twin resaws and is controlled by very sophisticated optimisation systems that maximise lumber value recovery. These large log lines have log rotation and positioning capabilities and make use of thin kerf multiple circular saws with sophisticated curve sawing capabilities.

Over the last ten years, conversion technology has evolved at an very rapid pace; so rapid that some systems are far from being perfect, and those responsible for their operation and maintenance do not fully understand all of their intricacies. Efforts have to be expended on improving optimisation software and ensuring that mechanical components can implement the intended breakdown solutions. Training of maintenance personnel and process engineers is also needed to ensure that these sophisticated conversion techniques are being used in the most efficient manner.

Canadian softwood lumber mills process species from the spruce-pine-fir (SPF) group throughout most of the country, including the BC Interior. On the BC coast, the main species are the hem-fir group and Douglas-fir. Cedar lumber is also manufactured on the BC coast, and production methods are similar to those used with other softwood species (although the product mix is very different in cedar mills). Aspen, although not a coniferous softwood, is frequently processed in the same manner as softwoods in areas, such as Alberta, where it is abundant. White pine, on the other hand, tends to be processed in the same facilities as hardwoods, particularly in Eastern Canada.

4.1 Raw Material

Existing Technology

As sawmills attempt to diversify their product market mix, flexibility in the manufacturing process becomes more critical. Mills must be able to shift cutting programs according to market demand, which means that the right log must be allocated to the right cutting program. Resource allocation in the context of production planning and control involves the integrated optimisation of each part of the production process starting with resource management and ending with the final customer. Linear programming (LP) is a technique specifically designed to optimise the allocation of available resources. The technique is well suited for co-ordinating the goals of forestry, logging, production and sales into a unified strategy.

The development of LP models requires accurate data describing the sawmill's raw material supply. Integrated woodlands and processing analysis of this type allows the determination of the optimum allocation of a timber supply to alternative mill sites, or to alternative products. The effect of alternative logging plans or raw material sources on the operation and the product out-turn of the sawmill can also be determined.

It must be emphasised that results are only as good as input data. Estimated future log supplies, productivity, sales volumes and lumber prices are used to generate a plan that will impact today's operation; care must be taken to ensure these estimations are explicit. Managing LP models is likely to be a full-time job for one individual.

Most softwood lumber producers in Eastern Canada haul the resource to the mill in the form of tree lengths. This method of operation provides an opportunity to sort trees by species directly at the cutting site. Occasionally, a company with two or more sawmills in the same geographical region will sort by size and species to maximise efficiency of breakdown equipment and provide value-added opportunities.

Cut-to-length operations (i.e., cutting logs directly at the cutting site) are receiving a lot of interest as there is no need to haul residue to the mill. The cut-to-length method also allows for the elimination of large and expensive bucking operations at the sawmill. However, it complicates sorting by species because of the associated loss in productivity, which explains a renewed interest in species sorting at the green end of the mill.

Considering the small dimensions of the wood processed in Eastern Canada and the significant fibre content potential of tree tops for the production of pulp chips (5 to 15 per cent), it is doubtful that the method of harvesting will change drastically in the near future. Some companies have tried hauling their total resource allocation to a centralised bucking complex and allocating sawlogs to their two or three sawmills located in the region. Results show that production costs increase significantly due to repeated handling and hauling of the material. Furthermore, conflicts arise between mills in relation to the size and quality of the logs allocated to each mill.

A major improvement is needed to reduce breakage due to repeated material handling. Studies have shown that between 6 and 15 per cent of tree lengths suffer some type of damage before reaching the headrigs. Since most of the damage occurs in the longer stems when they are reclaimed from inventory, it may be worthwhile looking at sorting and inventory strategies to reduce lumber recovery losses related to stem breakage.

Mills are occasionally faced with the challenge of processing large quantities of fire- or insect-killed trees in a relatively short period of time as dead wood is susceptible to sapstain and other biological damage.

Incremental Technological Innovation

- *Develop accurate measuring equipment to assist harvesting operators with topping and bucking decisions. This equipment should be standard throughout industry so that information can be collected by various users and processed for their respective needs. Ideally, this equipment should also integrate downstream information from the mills.*
- *Sort out trees and logs for optimum allocation among various uses (e.g., sawing, veneer, pulp, composite panels, etc.). This needs to be done as early as possible, but practicality will vary with circumstances (e.g., existence of a central sorting yard, number of companies involved, degree of integration among various mills).*
- *Provide cut-to-length operations with more accurate downstream feedback to optimise log conversion potential.*
- *Modify handling methods to reduce breakage and other damage.*
- *Generally create data links between sawmills and optimised log processors for timely parameter updates..*

Breakthrough Technological Innovation

- *Develop techniques based on artificial vision and image analysis to scan forest stands either from satellites or from aircraft in order to create comprehensive databases for forest management and basic log allocation.*
- *Provide full data integration between forest managers, harvesting operators and log users to generate a single database accessible to all, and to facilitate rational resource utilisation decisions.*
- *Develop a supply chain utilisation system to integrate all supply inputs affecting profitability into decision aids for improved profitability.*

4.2 Log-Yard Management

Existing Technology

The primary aim of log yard management is to ensure that an adequate supply of logs is available to the mill. Consequently, the characteristics of the yard are greatly affected by such factors as the number of different species groups being processed in the mill, the types of operations the yard supports (e.g., a sawmill, several sawmills, a sawmill and a plywood mill, etc.); most of all, yard management is affected by logging operations. While, in some cases, it may be feasible to organise log delivery on a just-in-time delivery schedule, this is just not possible wherever logging operations depend on winter roads.

Log yard operators place the logs into storage in such a way that they can be recovered with minimum damage, maximum flexibility and at the lowest possible cost. Truck load capacity log stackers are commonly used to handle stems and logs in the yard. These machines are fast and effective, and a skilled operator is generally able to minimise log damage and breakage, however, they require that the yard be flat and firm. Log cranes offer high log storage volume per hectare of yard area, and minimise log damage, but with a single unit typically responsible for the entire inventory, maintenance and downtime issues become critical. Heel boom storage has a number of advantages including low damage, low capital investment, enhanced sorting capability and soft deck areas. However, these systems are the least productive. Generally speaking, reductions in log damage would require some operator training, combined with emphasis on quality and value, a comment that will be repeated throughout this document.

Softwood mills try to adopt a first in / first out strategy but it is not always possible due to various constraints pertaining to species (e.g., balsam is difficult to debark in winter) or harvesting conditions. Mill managers are increasingly aware of damage and losses associated with infestations by insects and the impact of dryness and stain on product value and market acceptance. Inventory should thus be rotated each summer to avoid excessive drying and subsequent loss of recovery. Bundling of logs can help reduce breakage, allow for more efficient and faster log handling, and make it possible to increase storage height. Bundling systems must be evaluated in terms of materials cost and reusability.

Even though log sorting in the forest would favour optimised fibre use with minimum yard inventory, in practice mills tend to prefer sorting in their own yard, where they have control and precision can be greater. Providing precision in the forest, as suggested above, would alleviate some of these fears. For some time, however, emphasis is likely to be on sorting at the mill. Even in this situation, the benefits of sorting must be weighed against handling costs, breakage and the risk of having to contend with higher inventories. In addition to improved handling technology in the yard, more sophisticated management tools, capable of simulating scenarios to recommend most valuable solutions, would be in order.

Incremental Technological Innovation

- *Develop and implement sorting and inventory strategies (including the use of log inventory control tools) to reduce lumber recovery losses related to stem breakage, insect attack and fungal degradation in the lumber yard.*
- *Develop inventory control tools integrating mill requirements as well as all factors affecting log quality and value to facilitate optimum decisions by the yard supervisor.*

Breakthrough Technological Innovation

- *Re-evaluate yard management principles and log handling equipment performance with a view to minimising holding time, eliminating log damage, and increasing supply flexibility. Develop decision-aid tools to support optimum decisions. Assuming that information has been obtained on forest stands and expected mill requirements, these could include software to simulate scenarios and recommend best yarding solutions.*

4.3 Log Protection

Producing wood products of the highest value requires attention to maximising value at the resource level. The increased cost of logs and the need to maximise value from them is driving the interest in protecting logs from degrade, beginning at the point where the trees are cut down. Trees felled with mechanised harvesting equipment are usually damaged in the process, either from the holding rollers or from the delimbing knives mounted on the machines. Spiked steel rollers often result in physical damage to the logs, causing loss of wood (from tearing and holes) and loss in quality (from compression marks which penetrate up to 20 mm). This damage has been well documented by the Forest Engineering Research Institute of Canada (FERIC). The sapwood part of the tree, which contains the most clear wood, is heavily affected by harvesting and other rough handling of logs. Such damage can result in lower volume or value yield from the log. For example, sawn boards which carry the marks of the rollers might be of lower value than they would be without this damage. Furthermore, fungal deterioration, particularly bluestain, is often associated with spiked rollers or with bark damage where the bark has been removed in handling. Modern harvesting procedures and subsequent log storage can therefore result in a significant loss in value of the product derived from the logs.

Staining fungi can grow slowly at temperatures barely above freezing but their optimum temperature range is 15 to 25°C. Stain problems are more likely to develop rapidly when ambient temperatures approach about 15°C. Staining fungi produce visual damage but have little effect on the strength properties of the wood. In logs, stain can appear over periods of a few weeks to a few months following felling, depending on the wood species, the weather, and the storage conditions. Pines, often the softwoods of choice for many value-added end uses, are particularly susceptible to bluestain. In general, stain can be reduced by minimising log storage periods. Logs that are harvested and not yet transformed during hot and humid periods (late spring to mid-fall) are susceptible to fungal infection.

Bluestain has often been considered by sawmill staff to be an inevitable occurrence in wood processed in sawmills. Sometimes this is the case, for example if the mill's log diet includes beetle- or fire-killed trees which have developed stain in the standing tree. It is important, however, to consider whether anything can be done to reduce additional stain development in what would otherwise be clean logs. The main methods used to protect logs from bluestain in various parts of the world are: (1) holding logs in water (ponding); (2) water spraying or sprinkling; or (3) chemical treatment with fungicides or insecticides. Water storage is the traditional method of protection used by mills on the Pacific coast; it has the advantage of cleaning up the logs. Spraying or sprinkling also provides excellent protection of softwood logs from degradation; however the lack of availability of water at the mill, the need to recycle the water, and problems related to cold weather operation have limited the use of such techniques. Sprinkling is more commonly used with hardwood logs used to produce appearance-grade products, during the most critical period of stain development, from May to September.

Unlike other countries, Canada has no tradition of using chemical pesticides for the treatment of logs to prevent bluestain. Although the need for log protection is increasingly recognised, it is unlikely that traditional chemical treatments will be adopted because of negative public perceptions of the impact of pesticides on the environment. To be effective, such chemicals would have to be applied shortly after felling so the opportunity to treat the logs chemically in a closed non-polluting treatment system (which could be done in a sawmill yard) is limited.

Any measures taken to control stain, whether in the forest or in the sawmill yard, need to be environmentally benign. Biological control methods seem to offer the greatest practical promise as a protection method in the future. Research is currently being done on biological wood protection, using fungal (e.g., albino staining fungi) and bacterial protectants, and has progressed considerably in recent years. An integrated approach, wherein an alkali (to modify the pH of the wood) and a biological control agent are combined in order to improve the performance and the uniformity of the protection, is also under development. As with chemical pesticides such bio-pesticides must be registered under the Pest Control Products Act administered by the federal government's Pest Management Regulatory Agency. Canada has one of the most rigorous pesticide registration processes in the world, and such registrations are expensive and lengthy.

Incremental Technological Innovation

- *Re-evaluate harvesting and log handling equipment with a view to minimising damage to bark and applying some form of protection to exposed wood.*
- *Minimise interval between tree felling and processing in the sawmill, especially during warm weather to avoid fungal degradation. If logs are sorted by species, this could include shorter rotations for the more susceptible species.*

Breakthrough Technological Innovation

- *Implement industrial application of biological or integrated biological-chemical log protection treatment to reduce fungal degradation with minimum environmental impact.*

4.4 Bucking at the Mill

Existing Technology

In Eastern Canada, softwood logs are typically bucked with a single- or a multiple-stem bucking system. Productivity is maximised through multiple-stem bucking, where five to eight stems are bucked simultaneously. In large stud operations, where log counts are extremely high, up to 20 stems can be processed per cycle. Although productivity is maximised, the multiple-stem process provides little consideration for the quality of sawlogs produced, or for value recovery.

Single-stem bucking offers a higher degree of flexibility in that individual stem characteristics can influence operators' decisions. To achieve throughput requirements, several single-stem bucking systems are used in parallel. In the last five years, the approach to single-stem bucking has been modified slightly. Trees are still debarked prior to bucking, but trees are bucked on a large deck, with saws positioned at predetermined locations. All sawlogs produced are scanned for diameter and length. When diameter is below requirements, logs are directed to the chipper to be converted to pulp chips, and the longer logs (16 feet) manufactured from the butt of tree lengths are re-bucked into two stud logs.

Major eastern sawmillers have shown little interest in optimised bucking. While the many advantages of computer-controlled bucking are acknowledged, the relatively low lumber production levels of most softwood mills and the high capital cost of bucking optimisers tend to make their acquisition hard to justify. Trimmer optimisers add roughly five per cent in recovery and will be favoured since the whole production is processed there. Furthermore, log throughputs being so high, major producers would require several bucking units to meet productivity requirements. Mills equipped with various more or less sophisticated systems see big improvements in many ways; however, widespread implementation of bucking optimisation in the east would require that systems be much more productive and economically accessible. Economic studies would help provide guidelines to mill owners.

On the coast of British Columbia, manual bucking is still the most common method; only about 30 per cent of mills use optimised bucking. Since logs are delivered to the mills as multiples of the final target lengths, there appears to be less of a need for computerised decision making. In the BC Interior, nearly 50 per cent of mills use optimisation at the bucking station; while in Alberta, more than 75 per cent are optimised. This can be explained in part by the fact that capital expenditures have fallen in BC in recent years and most of the expenditures have been in the Interior. Equipment used in both regions of BC is older (average age 11 years) than equipment used in Alberta (average age 6 years).

As a result of limitations in both time and computing power, early bucking optimisers could not simulate the sawing of each bucked log segment in real time at the speeds required in a sawmill. To circumvent this problem, look-up tables were used. These tables store pre-calculated values for logs in various length, diameter and taper classes. The scan data are used to determine the closest fit with a tabled log, and its value is pulled from the table. Since logs come in an infinite variety of shapes and sizes, it is not possible to evaluate every conceivable log shape prior to scanning. Systems using look-up tables thus do a poor job of determining the value of lower grade logs.

Recent advances in computing power now allow the on-line determination of lumber yield from each log, and the majority of new optimised bucking lines are able to process in real time. However, many look-up table based systems are still operating. It is important that sawmills be able to accurately evaluate the costs and benefits of utilising real-time systems as compared to systems using look-up tables.

Another important limitation of bucking optimisers concerns the accuracy of the scanning systems employed. Most optimisers utilise x-y scanners, but as true-shape scanning becomes more prevalent in the industry, sawmills need to understand their potential benefits. Without accurate scan data, the optimisation program cannot arrive at the optimum bucking solution. It is therefore critical that the log be stable on the conveyor as it passes through the scanners. This is particularly challenging in the presence of sweep and crook because misshapen logs have a greater tendency to bounce or slip during scanning. Slipping also causes the encoder to overestimate the length of the log. Prior to moving to true-shape scanning, there is a need to clearly quantify how the range of scanning error resulting from the transport system relates to any anticipated improvement in scanning accuracy.

In cold weather climates, improvements to scanning and bucking technology may be restricted by the fact that bucking is normally carried out in the open air.

Incremental Technological Innovation

- *Introduce continuous monitoring of length and diameter breakpoints of bucked logs, and replace look-up tables with real-time information in order to support better quality decisions.*
- *Develop and install precision stem transport and holding systems to minimise log movement during scanning and cutting operations. The improved system should provide for easy evaluation of its performance.*
- *Envisage cleaning stems before scanning (log ponds?) as dirt on the bark makes for erroneous scans. Cleaner logs would also protect tools from damage further down the line.*
- *If stems have been scanned and identified in the forest or in the yard, correlate output from the bucking operation with input.*

Breakthrough Technological Innovation

- *Develop and install through-the-log scanning equipment to provide input to optimising models and to guide bucking decisions. If through-the-log scanners became available, the bucking operation might not require the same precision of information as the head-rig. See Section 4.7 for a more detailed discussion of log scanning technology.*

4.5 Debarking

Existing Technology

There are many types of debarkers available but, in softwood sawmills, the most popular is undoubtedly the ring debarker. Typically, six air-loaded tool arms attached to a rotating ring provide a scraping action over the surface of the log, causing the bark to shear at the cambium layer. The relationship between the ring rotation speed, the number of tool tips, and the width of the tool tips is calculated to provide tool coverage with about five per cent overlap at operating feed speeds.

The ideal debarking machine is capable of providing high piece counts from a wide range of species and operating conditions, such as green, dry or frozen. The machine should also be able to handle a range of diameters and lengths.

With respect to debarking, Eastern Canada has operating conditions that are more difficult than those in much of the west. Logs tend to be smaller, and often are dryer and softer, making fibre damage more likely. Log damage typically occurs from tool arm and feed roll opening and contact; short log processing is more common in the east, which means that more ends must enter and leave the equipment.

This sector of the sawmill has been neglected for many years as it is very difficult to measure and quantify the economic impact of debarker fibre losses. Debarking equipment is efficient and capable of doing a good job. However, due to cost considerations, the equipment does not always receive the required attention, and replacement of worn parts is too often stretched to unacceptable limits. An automated quality control system monitoring the quality of the debarking process and providing feedback on its efficiency is urgently required.

Recent technological developments in debarking, such as lighter debarking tools and variable tool pressure according to log diameter have resulted in significant increases in efficiency. Logs are now well debarked while fibre losses are minimised. Future needs relate to improved debarking efficiency under winter conditions when it is very difficult to debark species such as balsam fir. Several attempts have been made to find economical means to break the bond between bark and wood fibre when logs are frozen, but research is still required in this area. Material handling before, within and after the process is difficult. Efficient debarking also requires that logs be fed one at a time.

Forest fires in BC and Alberta in recent years have left certain regions with a glut of burned wood to be processed. This has presented the industry with some unique challenges regarding debarking. Dual ring debarkers have shown to be effective in dealing with burnt wood, while some mills using a single ring debarker have added a second in-line. Many mills have designed a carousel system where logs that have not been satisfactorily debarked are kicked out and cycled back for a second pass. Where chip markets stipulate that no charred wood is permissible, "Rosserhead" debarkers have proven to be effective. Another option involves the use of flail ring debarkers for removal of the bark at the logging or sorting site. This option has not been popular in the west, but, if environmental concerns over handling and storage of burnt wood and the resultant leaching and run-off should intensify, debarking in the woods may become a more attractive option in this situation.

Incremental Technological Innovation

- *Develop and implement automated debarking quality control systems (e.g., based on artificial vision and image analysis) to check debarked logs for bark presence and damage, to check for wood fibre in bark residue, and to check for bark in chip flow.*
- *Develop and implement superficial bark thawing systems (e.g., infrared or microwave radiation, hot ponds) as a means of improving debarking quality. Some systems do exist, but they need to be adapted, and their cost-effectiveness demonstrated. If throughput is a problem, superficial treatment could be a second-pass operation restricted to logs that were not properly debarked in the first pass.*
- *Add variable speed drives to the feed system and to the ring, as well as controllable tool pressure, in order to give operator more options when dealing with hard-to-debark logs.*
- *Improve log holding systems during debarking, as well as overall log handling for the debarking operation.*

Breakthrough Technological Innovation

- *Develop a smart debarking system whereby a true-shape scanner determines the shape of the log under the bark, and a shaper-type tool removes the bark under computer control.*

4.6 Scanning and Positioning Systems

Existing Technology

Log scanners are most commonly used to measure the external profile of logs either to sort out the logs or to position the logs and optimise sawing decisions. Different types of scanners can be found in sawmills:

a. Shadow scanners are based on infrared radiation. The log cuts a light curtain generated by an emitting head, and the log diameter is read by a receiving head. Resolution is usually 2.5 mm (0.1 inch), which is the distance between light beams. Some systems run on a single axis (one pair of heads), while others run on two axes (two pairs of heads) or even three axes (three pairs of heads). Two-axis scanners are the most popular as they can provide a three-dimensional profile of a log (showing curvature) in a fairly realistic manner.

b. Laser scanners rely on a high-resolution camera and triangulation to read the image of a laser beam bouncing off the log. A series of points corresponding to the periphery of the log provides a precise definition of log profile. True-shape scanners can read hundreds of points per section at 25-mm (one-inch) intervals along the log. Most modern optimisation systems use this approach.

Other scanning systems under development include x-ray, ultrasound and magnetic resonance imaging along with computer tomography imaging to detect internal defects in logs. However, these systems are expensive, still of questionable accuracy, and they do not function at the speeds required in a sawmill.

Scanning problems relate to log transportation and holding as lateral movement of the log obviously leads to erroneous measurements. Sharp chains do not hold logs firmly enough, especially in the winter time. Equipment manufacturers make use of filtering algorithms to minimise the problem, but this may have negative effects. When filtering is too severe, actual log distortions can be eliminated together with actual "noise."

Snapshot scanning presents the advantage of scanning logs without moving. However, high resolution requires several heads, which makes the system expensive. Radar scanning techniques offer even greater resolution (1 million dots per head) and may also be used for snapshot scanning. It is also quite costly.

Incremental Technological Innovation

- *Develop and calibrate site-specific descriptions of correlations between external characteristics and extent of internal defect as a substitute for internal scanning.*

Breakthrough Technological Innovation

- *Develop and implement multi-sensor internal scanning techniques so that internal defects (decay, knots, etc.) may be taken into account in bucking and sawing decisions.*

4.7 Log Sorting

Existing Technology

In Eastern Canada, log sorting is usually performed by scanners solely to segregate sawlogs between production lines or log accumulation decks according to pre-programmed cutting patterns. Log sorting is rarely performed to meet product or end-market requirements but to maximise productivity.

In spite of the continuing predominance of commodity production, some mills have shown interest in European methods which place more emphasis on end product/market diversification. Several companies have dedicated some of their operations to specifically address value-added products and niche markets. These mills place more emphasis on sorting strategies and end-product. Their number is expected to increase as the need is felt to diversify production and maximise value recovery. As with most optimising operations, small logs present a greater technical challenge (because of size, feed speed, value, etc.), with a lower return expectation (because their product mix is more limited).

With the trend toward product diversification, there may be a need in the near future for some type of log quality segregation for softwood logs based on the type of external defects or the knot distribution. The grading process could eventually require an automated system with scanning and defect identification capabilities. Material handling before, within and after the process also presents frequent difficulties.

4.8 Primary Breakdown

Existing Technology

In the past ten years, eastern lumber producers have made major technological modifications. A majority of sawmills now operate the most advanced primary breakdown equipment available, similar to the systems found in western mills. These machine centres are fully optimised and equipped with log rotation and log positioning capabilities which are controlled by very sophisticated scanning systems.

The weak link in the primary breakdown process is the mechanical components that must implement breakdown solutions identified by the optimisation software. Mills currently have to accept log movement at every step of the log positioning and breakdown process. The challenge is great as it requires precise log rotation and log positioning as well as a transport mechanism that will maintain the work piece in the proper position. The challenge is even greater when this has to be performed at speeds in excess of 150 m/min (500 feet/min) and with log sizes under 7.5 cm (3 inches) in diameter in mills processing small logs. Improving the accuracy of log turners and log transport and holding systems will generate significant increases in lumber volume and value.

Due to high throughput requirements in the east, optimisation software is not used to its full capability. Time constraints imposed on the software to ensure high piece counts often result in the best breakdown solution being retained from only a partial list of possible breakdown solutions. Computing and software capabilities have to be improved to ensure that the optimisation process is completed before a solution is retained.

Canter: Large log lines usually operate a chipper-canter close-coupled to a twin band or twin circular resaw to manufacture a two sided cant. On a small log line, one can find various types of headrigs, ranging from a chipper-canter to a completely integrated machine centre like a four-sided canter (e.g., Hewsaw, DDM6, etc.). The latter machine centres combine primary and secondary breakdown operations in a single machine centre. They also make use of advanced scanning and curve sawing capabilities, but log rotation is somewhat neglected in order to maximise log throughput. The degree of optimisation varies greatly at this machine centre. Material handling is often difficult and sharp chains cause problems in many mills. Chip quality is maintained with more knives and variable electric drives; however, adjustments and maintenance of the knives and adjacent parts are critical, as is the selection of suitable AC drives.

Twin bandsaws: Material handling is also difficult at this machine centre. Sharp chains remain a commonly used system to push logs into the headrig. Twin bandsaws are expensive equipment requiring a great deal of care since they rely on good filing practices and proper maintenance. Alignment, lubrication systems, sawdust deflectors and tensioning systems are frequently out of order. When close-coupled to a canter, twin bandsaws tend to contaminate wood chips with sawdust.

Scraggs: Old systems with heavy kerf are still present in a few mills. Operating costs associated with such systems are very low although fibre loss is important. When changes are implemented to adopt thin-kerf sawblades, the adjustments required in the filing room for tensioning the blades may be hard to implement. Guiding systems are weak in many cases. When splined saws are used, wear occurs at the eye. Most use a small collar bolted to the blade to increase the contact area.

Double-length infeed: Double-length infeed (DLI) stations provide maximum optimisation. Advanced mechanical and hydraulic systems are used; the latter can be somewhat fragile in some cases. This is where the first black box can be found in the mill. Many mills do not have enough space to install a double-length infeed and resort to other means to try to achieve the same results with their equipment (single-length and length-and-a-half infeed).

The most popular primary breakdown system being installed in Western Canada at present is a combination double-length infeed with chipping canter and twin or quad saws (usually bandsaws). This is a highly optimised, high production line, but it needs some improvement in log control. If this could be combined with a continuous end-dogging log transport system so that the log position is rigidly controlled through scanning and turning as well as chipping and side board removal, recovery of these systems would increase significantly.

Small log processors: These machines have become very popular with the industry in recent years. They are compact, and can process even very small logs at high speed. Their ability to process logs in one pass eliminates multiple scanning, positioning, processing, by-product disposal and their associated costs.

End-dogging: End-dogging is a very promising method of holding and precisely positioning logs as they are being fed through the primary breakdown machine. It minimises log movement, thereby allowing for reliable scanning. Its major drawback for small log producers, such as those found in Eastern Canada, remains limited productivity, but one unit is currently operating at 42 logs per minute in a Quebec stud mill.

Band-saw carriages: On the BC coast, the full taper, around-the-log sawing pattern using a single- or double-cut bandsaw with carriage is the most common sawing system. With this system, the head sawyer has complete control with respect to breakdown options. This allows the recovery of higher lumber grades such as clear and shop from large logs. Carriage scanners have been around for more than 15 years; they are useful for determining optimal log alignment, taper settings and the depth of the opening face. The scanning technique of using a curtain of photocells to detect the leading edge of the log on the carriage is still the most common method.

The main disadvantage of the bandsaw with carriage is the low level of productivity resulting from the need for multiple passes to break down a single log, and prospects for increasing productivity at this machine centre are limited. Bandsaws with carriages are also difficult to align. Bad alignment, rocked or stretched saws, setworks problems and incorrect size sets dictate the need for an in-line detection system allowing maintenance personnel to act quickly to correct problems.

Incremental Technological Innovation

- *Improve computing and software capabilities of optimisation systems so that the process may include all possible solutions, and that it is completed before a solution is retained.*
- *Evaluate the potential application of end-dogging to a broader range of mill conditions, as a means of reducing log movement and closing the gap between calculated and actual sawing solutions.*
- *Generally re-evaluate log holding technology with the objective of eliminating movement during scanning and sawing operations.*
- *Continue developing technology to improve chip quality and lumber surface quality at the canters.*
- *Develop tools and techniques to facilitate alignment and maintenance of bandsaws.*
- *Develop and implement continuous monitoring of saw performance in order to detect trends in sawing quality and identify problems before they cause loss of production. This can also be used to adjust feed speed to log conditions. Such systems are already in existence, but they need to be adapted.*
- *Develop and implement on-line product evaluation and feedback systems to compare products obtained to optimum solutions calculated by the computer. This would include thickness and*

width measurement as a minimum, but it could also scan for surface characteristics (scoring, rough surface, etc.) to detect saw wear, saw filing or other problems.

4.9 Secondary Breakdown

Existing Technology

Multiple circular resaws are the most widely encountered secondary breakdown machine centre. In small mills, they are still manually fed by operators with laser lines used as references. Larger, more modern mills have optimised infeeds where cants are scanned and positioned mechanically before processing. Scanning accuracy is not always on target for some in-line systems. The introduction of chain beds has corrected the situation for most applications. Feed speeds are very high. In guided machines, saw kerfs are mostly in the 3.0 to 3.3 mm (0.120 to 0.130 inch) range. With good controls and equipment maintenance, however, some can achieve 2.8 mm (0.110 inch). Some leading-edge mills are running circular saws at supercritical speeds using kerfs in the 2.0 to 2.3 mm (0.080 to 0.090 inch) range. There are several types of multiple circular saws, i.e., single or double arbor, thin-kerf multiple resaws and both straight or curve sawing versions.

Developments such as thin-kerf guided blades and splined arbors have significantly improved sawing accuracy, reduced sawdust and permitted reductions in lumber target sizes. In the future, we should see more double-arbor machines to allow for fast speeds. New machines come with timing belts on the feedrolls and arbors. Alignments are often deficient, and guiding systems are relatively fragile. Available power is insufficient in many applications. New arbor types are offered. Gear type arbors are doing well. Curved boards can be a challenge for downstream equipment, so that companies using curve sawing systems are often forced to choose between setting parameters that limit bow in sawn products (which prevents jam-ups in downstream equipment) or investing in equipment specifically designed to efficiently handle bowed lumber.

In the past ten years, secondary breakdown has come a long way in terms of optimising both straight or curve sawing. Systems are so sophisticated that it has become difficult to verify their performance. Optimisation software and scanning devices are well ahead of the mechanical devices that must execute the selected instructions. There is a need to develop an intelligent system capable of providing feedback on the machine centre's capability to implement selected breakdown solutions such as log positioning, sawing pattern and expected products. Improved transport systems to ensure that the cant does not deviate from its intended path are urgently needed.

The number of small bandmills with wheel diameters of 900 mm (36 inches) or less has increased dramatically in the last few years and they play a significant role in the secondary manufacturing industry. As bandmill design and blade technology improve, these machines may work their way into the primary sawmills on the small log lines.

Board edgers: In BC and Alberta, more than 60 per cent of board edgers in use are optimised. There are marked differences, however, between the coast of BC and the rest of the west. In Alberta and in the interior of BC, more than 80 per cent of board edgers are optimised, while on the coast of BC only about 40 per cent are optimised. This is an indication that technological innovation has been directed at mills producing dimension lumber rather than at those producing specialty products. Automated systems in application today are very good at optimising for geometry but systems that optimise around defects have not yet been perfected.

When equipped with optimisation devices, edgers are almost always in conflict with trimmer optimisers, and ways must be found to harmonise the two systems for optimum edging and trimming decisions. Surface finish varies when a top head is present. Few suppliers offer edgers with three chipping heads. Handling of the boards prior to and after the process is not always fine-tuned.

In some mills, edger capacity can be borderline, causing this machine centre to be a frequent bottleneck. Typically, scanner capacity can be 60 pieces per minute or more while edger capacity is often less than 40 pieces per minute.

Trimmers: As with board edgers, the majority of board trimming systems on the coast of BC, nearly 80 per cent, are not optimised, while in the rest of Western Canada, nearly 80 per cent are optimised. New systems are being designed with a focus on productivity as well as enhanced flexibility. Speeds of between 120 and 150 lugs per minute are common, as are features such as odd-length trimming, "Cut-in-Two," and centre defect trimming. Enhancements aimed at more effectively handling bowed boards from curve sawing multiple resaws are needed.

More and more multiple drop-saw trimmers are being installed. Small saws revving at high speed are needed to give a smooth trim (even more important at the planer mill). Small hydraulic motors perform satisfactorily in this application. For large boards, however, care must be taken to supply sufficient power, since hydraulic motors will stall just above design conditions. Positioning is relatively inaccurate in most cases. Some are using hollow top saws at the planer mill. Hollow ground saws are regaining favour in this application since piece count is very high. Drop fences for re-edging are not always very efficient and the situation is worse with curved boards.

Incremental Technological Innovation

- *Develop and implement systems for enhanced shape scanning.*
- *Develop and implement transport systems better able to handle misshapen pieces without damage, particularly bowed boards produced by curve-sawing. These probably need to be linear systems.*
- *Develop techniques and tools to facilitate double arbor saw alignment.*
- *Improve computing and software capabilities of optimisation systems so that the process may include all possible solutions, and that it is completed before a solution is chosen.*
- *Improve lumber holding systems to positively prevent lateral movement during cutting.*
- *Improve fencing systems to provide larger number of options while improving accuracy.*
- *Develop and implement continuous monitoring of saw performance in order to detect trends in sawing quality and identify problems before they cause loss of production. This can also be used to adjust feed speed. Such systems are already in existence, but they need to be adapted.*
- *Develop and implement on-line product evaluation and feedback systems to compare products obtained to optimum solutions calculated by the computer. This would include thickness and width measurement as a minimum, but it could also scan for surface characteristics (scoring, rough surface, etc.) to detect saw wear, saw filing or other problems. Linking could be used to control variable feed speeds, variable cutter speeds (chippers) or variable saw speed.*
- *As an interim quality control measure, provide for the automated control of boards off-line, so that operators may be able to verify a reasonable number of controls (anything better than six boards a day would be an improvement in some mills).*
- *Continue the development and optimisation of sawing at supercritical speeds (see Section 4.11).*

Breakthrough Technological Innovation

- *Develop comprehensive scanning system capable of detecting geometry defects, other surface defects (decay, knots, splits, specks, etc.) as well as internal defects at industrial speeds. This system would likely be linear and include a variety of sensor types. The information could be used by both edgers and trimmers. It would also be an evolving system, capable of learning from its own experience ("neural" networks).*
- *Optimise sawing accuracy and surface quality to the point where planing can be replaced with a light sanding operation or totally eliminated, at least for some applications.*

4.10 Alternative Breakdown Concepts

In the past, experiments were run with a number of alternative techniques such as vibration sawing, slicing, etc. These techniques never reached the commercial stage, and they seem to have been totally abandoned. Water-jet cutting has been used for cutting out intricate shapes from sheet materials, including wood panel products, but it does not seem to offer any real potential in lumber production, mostly because the jet cannot cut through thick material. As for laser cutting, it has not found any application in mainstream lumber manufacturing.

Interviews with Forintek staff and industry representatives also brought up examples of wood products produced through different methods. In some cases, the wood was cut into modular sections and reassembled through finger-jointing, edge- and face-gluing. Engineered products of this type are covered in Section 7, Engineered Wood Products. In other products, wood is peeled, sliced or chipped, then reconstituted into products having the desired shape with the assistance of an adhesive. Products of this type (e.g., laminated veneer lumber [LVL], plywood, oriented strandboard [OSB], particleboard and medium density fibreboard [MDF] were covered in a previous Roadmap).

Other techniques have been proposed to replace cants and conventional square sections with patterns designed to maximise lumber recovery from logs; these are typically trapezoidal. The pieces thus obtained are subsequently assembled into slabs with the assistance of an adhesive, and ripped into the desired products. As with the recovery of boards or other small sections, the feasibility of these techniques is more dependant on economics than on technology, and they are more likely to become widely adopted as lumber value continues to increase. Gluing technology for structural products is described in Section 7, Engineered Wood Products.

4.11 Filing Rooms

Existing Technology

The main development affecting sawblades in recent years has been the introduction of thin-kerf blades and a generalisation of saw guides. These have allowed mills to significantly increase volume recovery by reducing kerf as well as sawing variations. New tools have been introduced in recent years to ease the filers' workload. First with levelling and now with tensioning, automatic saw preparation machines have had a weak emergence in filing rooms. The Video Tooth Inspector (VTI), developed by Forintek, has been fairly successful in Western Canada but interest has been more limited in Eastern Canada. Some American mills have adopted variable pitch bandsaws for their mills but very few are in use in Canada.

Most eastern mills use automatic top and face and side grinders with air cylinders; however, more mills are buying state-of-the-art grinding equipment. Most eastern mill owners have invested very little in their filing rooms apart from upgrades for guided saws. Many small mills still grind circular saws on manual equipment. Proper ventilation and enclosures are rarely seen, and very little attention is paid to health and safety issues. Some suppliers offer stainless steel sawblades and composite saws (e.g., brazable ceramic teeth) but a majority of mills do not seem to see significant benefits in this new technology. Some mills have been using circular saws at supercritical speeds to good effect; much remains to be learned, however, about these techniques and how they could be optimised.

With respect to chippers and chipper-canters, disposable knife systems have been available for some time, and they have met with a degree of success in the mills. Unfortunately, surface quality continues to be questionable, especially around knots, where tear-out problems tend to occur. One way around this problem consists of running the chipper-canter in combination with a saw; but this does not appear to be an appropriate solution.

The quality of saw or knife preparation does not always seem to be as high on the mills' priority list as optimum recovery and quality would dictate. What's more, the introduction of automatic tensioning or grinding machines may have led some mills to neglect human skills and the need for a specialist to assume responsibility for saw blade and knife preparation as well as feedback to suppliers.

Incremental Technological Innovation

- *Continue research and development on supercritical speed sawing and optimise blade characteristics and preparation for this purpose. Also develop appropriate guides and information on desirable feed speed, etc.*
- *Develop appropriate technology to improve surface characteristics produced by chipper knives.*
- *Evaluate and optimise new blade types (stainless steel, ceramic teeth, etc.) with respect to lumber quality and recovery, feed speed, ease of preparation, cost, durability, etc.*
- *Devise a method to accurately grind thin-kerf sawblades by preventing the teeth from bending.*
- *Investigate low environmental impact substitutes for cutting fluids used in grinding.*
- *Continue development and implementation of active guides.*
- *Continue providing saw-filers with techniques and tools to evaluate saw preparation quality.*
- *Develop and install lumber quality monitoring systems to provide saw-filers with systematic feedback on saw performance.*
- *Optimise saw-tooth geometry for improved surface quality in cedar lumber.*

Breakthrough technological development

- *Develop a system to detect rocks in logs in order to extend sawblade cutting life and avoid downtime.*

4.12 Sorting of Green Lumber

Existing Technology

Green lumber sorting has become more sophisticated in recent years. With competition increasing on the dry wood market, producers were forced to tighten up quality standards to improve finished product appearance (straighter wood) and to obtain a better moisture content distribution. Mills involved in value-added production, whether in the form of engineered or appearance products, need better quality drying (reduced moisture content variations among pieces, reduced moisture content gradient within pieces). Value-added being more species-specific than commodity production, these mills also wish to sort lumber into species categories.

In view of the problems involved in drying SPF species (subalpine or balsam), as a group, species sorting is being used to decrease the proportion of over-dried pieces; it also helps meet standard requirements regarding percentage of wet boards, and reduces costs significantly by shortening overall drying times. Some mills have been able to implement programs to sort the raw material by species, and this is usually done in the bush where the material is most easily differentiated by eye. Many mills find it impractical to consider sorting in the bush as the varying log sizes result in inefficiencies at the sawmill. As there are also variations in drying properties within species, mills have shown an interest in technology to sort by some other characteristics related to the drying behaviour ("dryability") of the material. Dryability is particularly affected by the presence of "wetwood" in some species such as subalpine and balsam fir, aspen and poplar. Wetwood occurs randomly within a tree, and it is believed to be the result of bacterial infection. Wetwood zones dry much more slowly than normal wood, and often result in wet pockets within otherwise dry boards.

The pre-sorting techniques currently available to the industry include those based on weight, radio-frequency (RF) power measurements, proximity sensors, MPB (laser) and specific heat. In a recent sampling of mills in Alberta and BC, approximately 25 per cent of the mills had installed some form of pre-sorting equipment. Scanners for pre-sorting systems are installed along the green chains of sawmills, and the information is used to physically sort the material at the bin sorter. One of the major constraints for existing, as well as new mills, is the need to install extra sorting capacity. Extra bins and the corresponding building space quickly become the major part of the investment when installing pre-sorting equipment. Mills have minimised the impact on sorting systems by limiting pre-sorting to one or two lumber dimensions or, in some cases, mixing two or more lengths in a sort. Other mills have been looking at alternative solutions, like adding an eight-foot sorter adjacent to the existing 5-metre (16-foot) sorter. The mixing of lengths causes other problems as most piling equipment in softwood mills is not designed to pile such material in a proper manner for drying.

Sorting relies on the human eye, and no commercial system allows effective sorting of similar species such as those in the SPF group. A few years ago, a technique based on the "sniffer" technology used for drug detection was explored, but, for a variety of reasons, the project was never concluded. More recently, a system based on the physicochemical properties of wood (acidity rate, pH) was developed and it is being tested in industry. It is quite likely that the eventual solution in most areas of the country will involve a combination of techniques rather than a single principle: for example, a species sorting system combined with either a weight or RF-power measurement system. As pre-sorting offers the potential to both reduce drying degrade and increase productivity, there will continue to be much interest in this area. Research is under way and should continue on characterising the drying performance of various species and searching out alternative pre-sorting as well as drying methods.

In addition to product criteria (commodity vs. value-added specifications), sorting criteria could involve such factors as lumber size and length, species, grade, moisture content, density and dryability (i.e., a combination of factors that describes the ability of a piece of wood to dry under specific conditions, or, in other words, a specific relationship between drying conditions and drying rate). Forintek-developed OASiS software allows the mills to sort lumber into lots with similar dryability characteristics, thereby limiting the need for more bins; software of this type should be further developed and complemented with economic analysis modules.

Incremental Technological Innovation

- *Investigate and develop other methods (multi-step sorting) to deal with expanding product categories.*
- *Develop and implement fast and accurate lumber sorting systems, based on live input, to allow for more efficient drying and reduced drying degrade. Sorting criteria could include species, moisture content, weight, and other factors identified as affecting drying quality (dryability).*
- *Provide reliable calibration procedures or correlations between on-line moisture meters, hand-held resistance meters and hand-held RF-power meters so that all moisture content measurements in the mill may be comparable and usable in common databases.*
- *Develop and implement methods to accurately measure the moisture content of frozen lumber.*
- *Develop and implement a system for detecting zones in rough green lumber that might result in drying degrade.*
- *Pursue the development and implementation of species sorting technology.*
- *Re-evaluate drying strategies (technical and economic feasibility) in view of expanding product diversification.*

Breakthrough Technological Innovation

- *Further refine the concept of dryability as a means of identifying products that can be dried in a single batch, thus limiting the number of product categories to be pulled out on the green chain. Develop system, based on a combination of sensors (density, moisture content, weight, species, etc.) to sort products into groups of equal dryability.*

4.13 Protection of Green Lumber

Existing Technology

Stain or mould problems can continue on green wood waiting to be shipped or to go into the kiln. Issues related to the protection of green lumber for shipping are covered in Section 4.17. Wood to be dried should be stickered and placed in the dry kilns as soon as possible after manufacture. Where delays are experienced, the wood should be allowed to air-dry in a location where air circulation is good. A few sawmills use small moveable roofs to protect stacked lumber from rain. Delays in getting material into the kilns in the warmer months may result in fungal growth on the lumber. Much of the fungal growth which occurs when the lumber is stacked will be surface stain or mould which will usually be killed by the kiln and removed by the planer. Sapstain control products are used whenever necessary (see 4.17).

4.14 Drying

Over the past 15 to 20 years there has been a steady increase in the proportion of dry lumber produced by softwood lumber manufacturers in Canada. There are variations in the proportion of lumber dried in the various lumber producing regions of the country. Differences stem from the fact that the eastern and western industry groups have historically supplied markets with differing demands. The industry in Western Canada has been drying virtually all of its higher-grade SPF production for quite some time, while Douglas-fir and hem-fir have traditionally been sold green. Market factors in Eastern Canada have been different and a certain amount of green lumber is still in demand. Heat treatment for phytosanitary purposes is also practised in a number of mills across Canada.

The industry in general has increased its drying capacity significantly over the past 10 years, with the greatest increases being in Quebec and the Maritimes. At the present time, approximately 80 per cent of all softwood construction lumber produced in eastern Canadian regions is shipped from the sawmill in the kiln-dried condition. It is anticipated that market pressures will continue to drive the need for more kiln-drying capacity in all regions (SPF in the east, hem-fir and Douglas-fir in the west).

The current drying operations and practices employed have all evolved around producing a relatively low-value, commodity product. As a result, the equipment and practices are all aimed at achieving low-cost and fast turnover. Product values and product lines have already changed and will continue to evolve. With every increase in value of commodity products or introduction of a new value-added product, drying becomes more of an issue. Much of the existing equipment in the softwood sector cannot achieve the demands being placed on it when drying such products. This will therefore require major upgrades to existing equipment and addition of new drying facilities.

4.14.1 Piling and Handling

Existing Technology

Virtually all softwood lumber producers use automated systems to pile lumber on stickers in preparation for drying. All of the equipment employed is capable of stacking softwood lumber, mostly in even lengths, to the requirements demanded for drying. The aspects that are critical are sticker spacing and alignment. Most mills try to sort all of their material by length before piling. This results in good square packages and the most efficient use of available kiln space. When mills need to pile random lengths, or odd lengths, extra warpage results from poorly secured boards. In addition, stackers were developed at a time when few mills dried short lengths, whereas it has become common practice to recover and dry lumber down to 1.8 m (six feet), or much less if a mill has finger-jointing capabilities. All such lengths need to be piled into a standard square bundle for optimum results.

Incremental Technological Innovation

- *Develop lumber stackers capable of piling lumber of short and mixed lengths into standard square bundles to accommodate a greater variety of products and facilitate short length recovery.*
- *Develop drying methods that do not require stickering.*

4.14.2 Drying Equipment

Existing Technology

Virtually all softwood construction lumber is dried in large, batch dryers operating on the heat-and-vent principle. A small percentage of mills use dehumidification equipment. Other drying systems, like superheated steam/vacuum drying, are mostly applicable to hard-to-dry products, such as the heavier hemlock sections, as well as hardwoods and value-added products. Because drying is the only batch process in a lumber mill, various continuous drying methods were explored in the past; these usually involved some form of a tunnel reminiscent of that used for drying veneers, but with clamps to restrain the wood and prevent warpage. None of these has reached the commercial stage.

4.14.2.1 Operating Principles

Heat-and-vent kilns achieve drying by adding heat to extract moisture from the wood, venting to regulate relative humidity, and circulating the air within the chamber to maintain uniformity in drying conditions. The only difference with a dehumidification system is the manner in which heat is added and how relative humidity is regulated.

Heat-and-vent kilns are differentiated by the operating temperatures they achieve. Kilns that exceed the boiling point of water at some point in the drying process are generally referred to as "high temperature" while all other systems are classed as "conventional temperature" kilns. In practice, there is no clear differentiation between conventional and high-temperature kilns. Many conventional temperature kilns routinely reach temperatures of 93 to 99°C (200 to 210°F), while high temperature kilns include systems that operate with maximum temperatures from 102 to 116°C (215° to 240°F). Although both types of kilns are widely used across the country, there remains some confusion as to the benefits and drawbacks of using either in particular situations. Past drying studies have focused primarily on drying rates. Today's industry is very much aware and concerned about drying quality, and further work is required on the effects of high-temperature drying on drying degrade.

4.14.2.2 Energy Source and Temperature Control

The majority of heat-and-vent kilns used in the softwood industry are equipped with some form of radiant heating system fuelled either with natural gas, oil, or wood residue. The reason for the predominance of this type of heating system is purely economic. Where a mill has access to a natural gas pipeline, and given the current low price of fossil fuel, there is not much point in looking at any other type of energy system. Other heat-and-vent kilns are equipped with direct-fired systems. This is generally in the form of hot oil, steam, or hot water circulated through finned tubing. The majority of these heating systems use hog fuel (bark and sawdust) to fire the boiler with a small percentage of mills using oil, natural gas, or propane.

Although the use of wood residue would seem a logical fit for a kiln facility, the high initial cost, supervision requirements and extra maintenance associated with a wood-residue-fired system all detract from selecting this type of equipment. Mills using wood-residue-fired systems are those that have some other incentive such as a need to dispose of wood waste or those that cannot easily (or economically) access purchased energy. Some advances in technology are required before wood residue becomes a practical alternative for the relatively small- to medium-sized power plants required for a drying facility. Of particular concern are wood waste storage, handling, and metering systems and pollution abatement equipment. Many of these technologies are further advanced for large-scale operations but the solutions do not lend themselves well to downscaling.

In theory, drying times and lumber quality should not be affected by the type of heating system employed. In practice, however, many older kilns, especially those with direct-fired burners, do not achieve good mixing of the combustion air with that in the kiln. As a result, there can be wide variations in temperature from one region of the kiln to another. This further aggravates problems with final moisture content uniformity. Solutions need to be found to help producers meet modern demand for uniform moisture content.

4.14.2.3 Air Flow

Internal fans are used in all heat-and-vent and dehumidification dry kilns. Air is circulated through the lumber stack to deliver heat and carry away moisture. The air flow through the stack must be fast enough to minimise the change in air temperature and relative humidity from one side of the load to the other. Requirements for air flow will vary with load width, species being dried, and drying temperature. Recommended air flow on new kilns drying at conventional temperatures would be 2.5 to 3.5 m/s (500 to 700 fpm) and up to 5 m/s (1000 fpm) on high-temperature kilns. Many kilns do not achieve these air flows, either due to the age or condition of the equipment.

Most new kilns are equipped with adjustable speed fans, but there does not appear to be any consensus on how to operate these for best advantage. Despite the fact that several studies have been conducted on the subject, there continues to be some confusion in the industry on when fan speed can be reduced without affecting drying time or quality.

4.14.2.4 Humidity Control

Most softwood kilns rely on the venting system for humidity control, and they are not equipped with any humidification system. However, as demands for final moisture content uniformity and stress-free lumber mount, mills are either installing new kilns with humidification systems or retrofitting existing kilns. Humidity is added with either live steam or water sprays. Another potential is to use the humidification system to moderate drying conditions at earlier stages in the drying process. Some schedule development work is required to support the industry in this area.

4.14.2.5 Kiln Control

Proper control of the drying operation requires specific information on the objective (i.e., target moisture content of the wood, allowable face-to-core gradient, allowable deviation within the piece, allowable deviation between pieces, allowable degrade, allowable over-dried pieces, allowable under-dried ["wet"] pieces, and external constraints of time and cost); it requires specific information on initial conditions (i.e., lumber size and mass, initial moisture content and temperature, species, pile characteristics, kiln characteristics, etc.), and the means to manage drying conditions (i.e., drying rate and its effect on stress development).

The majority of softwood drying operations are equipped with computerised kiln control systems. Aside from accurately monitoring and controlling temperature and humidity, most of these systems incorporate some technique to judge the progress of the material being dried. This is either done remotely by measuring temperature drop across the load or more directly through DC-resistance probes to estimate the moisture content of the wood. No techniques are available to accurately determine and track the moisture content of the load from start to end of the drying process, not to mention variability and internal stress. Some weighing platforms are available to monitor average weight loss and, from that, infer the moisture content, however, their use has not been perfected. There is no reliable equipment to provide board-by-board information of moisture content in a large softwood kiln.

In the absence of good devices to measure the moisture content of material being dried, the alternative remains with perfecting remote systems. All of the indirect systems currently available rely on measuring a characteristic of the kiln and relating it experientially to the moisture content of the wood. Another approach is to develop mathematical models to predict how wood reacts when exposed to certain environmental conditions. Fundamental work is under way in a number of countries, including Canada, on developing such models. Modelling offers considerable potential to refine and further automate the drying process.

4.14.2.6 Stress and Warp Control

As discussed above, stress develops in wood as a consequence of different drying rates, and it is one of the objectives of good drying schedules to find an acceptable compromise between drying cost (essentially residence time) and product quality (minimum degrade). The rules of the compromise vary with cost inputs and required quality output; consequently, different schedules are required for the production of commodity lumber and production of lumber for remanufacturing. Dead weights are sometimes placed on top of the loads to reduce warpage in the top layer, where less weight is applied on the material during the drying process, while air flow may be greater. One kiln supplier has developed an in-kiln device to apply the same sort of top restraint. While this approach provides a means of improving grade recovery, research needs to continue on the fundamentals of stress development with the aim of minimising warpage through combinations of sorting, scheduling and kiln control.

4.14.2.7 Kiln Size and Structure

Heat-and-vent kilns usually consist of insulated metal structures on concrete pads, with large doors designed to accommodate pre-stacked loads on carts. Kiln design has traditionally emphasised low capital cost; as a consequence, kiln durability has been questionable, and the resulting high cost of maintenance may explain, at least partially, why kilns are frequently found wanting in terms of insulation integrity, air tightness or even basic maintenance. It may be desirable to re-visit this issue, and to develop a better grasp of the cost factors involved in drying in relation to the value added by the operation; these cost factors should include the cost of poor performance as well as maintenance, operating and capital costs.

Kiln size is another economic consideration that bears re-visiting. Today's large kilns have been designed for commodity production; as demand is evolving towards a greater variety of products, and a greater variety of tighter specifications (especially for further value-added processing), large kilns may not be the best answer. Again, economic analyses are required to determine whether the quality attributes demanded by the market are best obtained in large kilns, smaller kilns or combinations thereof.

4.14.2.8 Alternative Kilns

Superheated steam/vacuum (SS/V) is a technique in which lumber is dried at low temperature (50 to 70°C), yet above the boiling point of water as the process takes place under a vacuum of approximately 20 kPa (200 mbar). At these lower temperatures, wood is stronger and therefore less susceptible to drying degrade. SS/V kilns produce excellent results for difficult-to-dry species (e.g., hemlock, alpine fir) and for thick (above 50 mm) lumber that would normally require three to five times longer to dry. Drying uniformity and high quality, in addition to fast drying times and reduced energy consumption, are the main advantages claimed by European lumber producers who have been using this technique for a number of years. Canadian tests have confirmed the potential of SS/V, but research is still needed to speed up the heating-up phase and to provide for equalisation and conditioning at the end of the cycle.

Radio-frequency vacuum (RFV) kilns operate on a similar principle, except that energy is provided by high-frequency alternating voltage. Wood itself is a poor conductor of electricity, but dipolar water molecules within the wood rotate millions of times per second as they align themselves with the changing electric field. This generates heat similar to friction, resulting in internal temperature/ moisture gradients and vapour pressures. Steam is forced outward along the path of least resistance—in the longitudinal direction through to the ends of the lumber.

RFV drying offers short drying times and high quality dried products with a reduction in warping, checking, twisting, and casehardening. It also eliminates staining and discoloration problems. Like the SS/V technique, RFV seems to be well suited for high-value products, or products that require very long drying times in conventional kilns, including lumber with wetwood.

Incremental Technological Innovation

- *Develop small- to medium-size hog-fuel-based energy systems for kilns.*
- *Investigate techniques likely to improve temperature uniformity in direct-fired kilns (new and retrofit).*
- *Optimise application of adjustable speed fans.*
- *Develop instruments and tools for the on-going (direct or indirect) measurement of actual drying rate in the kiln. Given the size of the kilns, this will likely require a number of sensors measuring temperature (dry- and wet-bulb) in various locations, wood mass and moisture content, and possibly some other indicators or combination of indicators with a strong correlation to drying rate and water extracted.*
- *Pursue modelling activities as a tool for more efficient kiln control.*
- *Optimise drying schedules for stress relief (use of humidification).*
- *Apply feedback from grading system as input for kiln control and drying quality control.*
- *Evaluate kiln characteristics (and related costs) in relation to expected results, and develop practical recommendations.*
- *Continue development work to adapt SS/V and RFV drying to a broader range of industrial applications.*

Breakthrough Technological Innovation

- *Develop and implement a kiln controller capable of integrating load input (lumber mass and size, lumber moisture content average and distribution, lumber temperature, species, pile characteristics, and dryability information), kiln characteristics, energy input, air flow characteristics, and production objectives (product quality, etc.).*

4.14.3 Dry Moisture Content Monitoring and Quality Control

Existing Technology

The most critical aspect of dry lumber quality, from the customer's standpoint, is conformance with the final moisture content requirement. The majority of softwood construction lumber is dried to 19 per cent or less, with smaller amounts being dried to 15 per cent, or even tighter specifications, for specialty and value-added products. Final moisture content variability, due to within- and between-species drying differences, has always been an issue for softwood producers. In-line moisture meters have become quite popular over the past 10 years as they are the only way of monitoring all production. It is estimated that 75 per cent of large softwood mills in Western Canada have such meters. In Eastern Canada, it is estimated that 60 per cent of the larger mills have them in place.

Most mills are using them strictly as a watchdog to ensure that the percentage of "wets" does not exceed acceptable levels. Only a few mills have "closed the loop" by setting up a system that ensures that all information makes it back to the kiln operator and that the kiln operator uses it as a diagnostic tool to evaluate his equipment and practices. Another potential use of in-line meters is to sort out material for re-drying.

Some confusion exists within the industry on the accuracy and reliability of in-line and hand-held meters. Some mills have also experienced problems with frozen lumber. The confusion stems from each meter being affected by different environmental and wood-related factors. Some laboratory work to confirm or develop new correction factors for both meters, and to identify proper operating practices would go a long way toward clearing up the confusion.

With most softwood producers, quality control in lumber drying is limited to final moisture content monitoring. More detailed and accurate moisture content information would be helpful in developing and refining drying schedules and ensuring maximum recovery of high-value grades or products from the available resource. An automated way of collecting information on lumber moisture contents and conditions prevailing in the kiln would also facilitate equipment evaluation and process improvement.

Incremental Technological Innovation

- *Develop technology to establish consistency between on-line moisture meters, hand-held resistance meters and hand-held RF-power meters so that all moisture content measurements in the mill may be comparable and usable in common databases.*
- *Develop and implement methods to remotely monitor moisture content and temperatures inside the kiln (see Section 4.14.2).*
- *Develop and implement methods to monitor kiln-dried lumber for drying defects (checking, warp, etc.) in real time and to analyse this information for kiln control.*

Breakthrough Technological Innovation

- *Develop and implement an integrated method to analyse all data pertaining to kiln-dried lumber production and relate it back to information collected at the dryers and at the sorting station in order to optimise sorting and drying strategies.*

4.15 Planing

Existing Technology

The planing operation consists mainly in giving lumber pieces uniform and precise final dimensions while clearing surfaces of irregularities left behind or created by previous operations. A majority of companies use older equipment that has been recycled or improved with new mechanical components. The productivity increases registered in the past few years have led a number of producers to acquire cutterheads with a higher number of knives (12 to 32) as a replacement for eight-knife heads. Helical knives and disposable knives in a helical pattern are also on offer as a means of improving surface quality and reducing planer noise. Feed speeds can now reach close to 600 metres (2000 feet) per minute with some planer models. Although the lumber feeding operation does not present any particular difficulty, the speed-up table and infeeds (pineapple rolls) cannot always keep up with the planer, which creates spaces between boards and causes impacts on the planer while reducing productivity.

As sawmills tend to diversify their product mix, they have to deal with more frequent dimension changes and, consequently, frequent planer adjustments. Industry uses more and more automatic adjustment systems to address this need. On top of being faster, these systems are more accurate and easier to use. In many mills, however, planers operate far below optimum in terms of grade recovery because maintenance and adjustments do not receive the attention they deserve, and because operators have not been sufficiently trained to optimise the process.

As a result of improved sawing quality and accuracy, modern planers are not expected to remove as much material as they did some years ago. In fact, it has been suggested that they might become unnecessary, or that they could be replaced with sanders to give lumber the required finish. Although Scandinavian producers have successfully marketed un-planed lumber in Europe for many years, this has been green lumber with high-quality sawn finish. It is uncertain whether a similar product would find market acceptance in North America. As for kiln-dried lumber, selling rough-sawn would require improvements in sawing quality (not to mention chipping) as well as drying quality. With the exception of some re-manufacturing and value-added operations which might actually prefer to plane their products after re-manufacturing (and benefit from slightly better tolerances), the potential for rough dry lumber appears limited in the North American context. Sanding-belt planers may have some potential in mills capable of producing highly accurate rough lumber.

Incremental Technological Innovation

- *Develop and implement the necessary technology for cutterheads to be positioned on the basis of knife trace for enhanced accuracy.*
- *Devise methods to simplify planer set-up and maintenance in order to improve quality and reduce down-time. This could be a combination of improvements to the machines, development of various tools to help operators, and operator training.*
- *Feed lumber pieces in a wane-up position to maximise grade recovery and lumber quality.*
- *Develop a device to monitor planer operation (material removed) and grade recovery in order to provide feedback to the kiln, the green sorting chain and the sawmill (see Grade Scanning section below).*
- *Improve knife grinding procedures to eliminate edge burning.*
- *Investigate the potential of sanding-belt planers as a substitute for knife planers in mills capable of high sawing and drying accuracy.*

Breakthrough Technological Innovation

- *Automate planer adjustments through computerised numerically controlled (CNC) technology, as well as knife changes.*

4.16 Grading and Trimming

Existing Technology

Mechanical lumber grading and mechanically evaluated lumber (MEL) have been known in Canada for about ten years. Mechanically-graded lumber is mainly intended for engineered wood products markets (I-beams and trusses). Two techniques are currently used to manufacture these products. The first one, certainly the most popular, is a mechanical constraint evaluation of wood by bending; the second uses X-ray technology to measure density, which is used to determine mechanical properties. See Section 7.3.1 for more information on machine stress-rated (MSR) lumber and its production.

Even mechanically-graded lumber needs to be inspected for appearance defects. This is done visually by the same graders who perform visual grading under rules set by the National Lumber Grades Authority (NLGA) or others. In efficient mills, graders are highly trained individuals who optimise value recovery on the basis of grading rules. In the recent past, lumber grading optimisers have been introduced to automate part of the visual grading process. There is no entirely automated grading system in operation in North America that can recognise all the required characteristics for lumber grading. Current optimisers recognise and measure lumber geometry (dimensions, wane, skip, holes) while the operator focuses on other defects (decay, checks, slope of grain, etc.).

The most frequently used scanning technology combination includes vision cameras and laser scanners. Vision cameras, either colour or black and white, are used to acquire information on surface defects such as knots, stains, shake and holes. Laser scanners are used to detect lumber shape characteristics such as wane, thickness, splits, checks, holes, and various types of warping. Some grading optimisers can operate at speeds in excess of 600 m/min (2000 lineal feet/min).

To the many sawmills that manufacture an increasingly wide range of products in terms of sizes and grading specifications (including foreign grades and specific client grades), optimisation technology offers flexibility and efficiency, especially when decisions are based on current product mix and product value. Defect measurement can be consistently accurate under a variety of rules, thereby optimising both value recovery and product reliability. Optimisers also make it possible to increase the number of fencing positions in the trimmer, which expands the potential for recovery in mills producing lumber in lengths other than the conventional 600 mm (two-foot) increments.

Like all optimisers, grading machines collect huge amounts of information on the products they process. This information can be analysed and used to further refine the grading process. It can be used to help with decision making (evaluation of scenarios) and for training purposes. This information can also serve as feedback for previous operations (e.g., planing, drying, sorting, sawing) and become an essential factor in an integrated process control system (see Section 4.18 on Overall Quality and Process Control). Systems are available for these purposes, but they are not currently used in any significant way.

The integration of multiple sensors using various technologies (laser, cameras, X-rays, microwave radiation, computer tomography or ultrasounds) could make it possible to recognise most geometric and visual characteristics essential for lumber grading, and make the operation entirely, or almost entirely automatic. They have not yet been applied commercially to lumber grading, but could become useful for operations serving re-manufacturing and value-added clients. As was seen earlier in this report, through-the-wood scanning has great potential in sawmills, mostly in the log and lumber breakdown process.

Mills equipped for finger-jointing or supplying material to finger-jointing operations recover trim blocks, and this needs to be taken into account by graders and grading optimisers. These mills would also find it useful to have equipment for sorting trim blocks into size, moisture content and possibly stiffness categories.

Incremental Technological Innovation

- *Further develop systems to improve grading accuracy, and help graders deal with a variety of grading specifications and economic inputs.*
- *Develop low-cost equipment to sort randomly oriented short blocks into size, moisture content and stiffness categories for finger-jointing (see Section 7.3.2 on Finger-jointing).*
- *Develop and implement optimisers capable of dealing simply and rapidly with frequent and complex grading parameter changes.*

Breakthrough Technological Innovation

- *Develop and implement an integrated grading system based on input from graders and a variety of sensors in order to increase value recovery and product consistency under a variety of changing specifications.*

4.17 Shipping and Lumber Protection

Existing Technology

Sawn lumber must be protected from degradation so that it can be delivered to the customer in a condition as close as possible in quality to what it was when it left the sawmill. Sawn lumber can be shipped green or kiln-dried, and the challenges of protecting the two types of lumber are different. Basically green lumber must be protected from fungal growth; whereas dried lumber must be protected from wetting.

A declining proportion of lumber is exported green, the bulk of it from coastal BC. The growth of moulds and sapstain fungi on this green wood is prevented through the application of a fungicide. Because they are classed as pesticides, fungicides must be registered by the Pest Management Control Agency under the Pest Control Products Act. Fungicides are diluted in water and applied through spray systems (more common in Western Canada) or dip tanks (the preferred method in

Eastern Canada). Samples of the treated lumber are routinely checked by analytical laboratories to check that the chemical has been applied at the right amount.

End-seal paint may be sprayed on the package ends of either green or dry lumber. In addition to giving the lumber a distinctive look for marketing, these paints may reduce checking of the ends. Sometimes packages of green lumber, especially larger dimension timbers, are given a cap wrapping wherein a single sheet of lumber wrap (see below) or loosely woven jute fabric is placed over the top of the package. Such wrappers prevent the drying and checking caused by wind and sun, and also protect sapstain control chemicals from degradation by ultra-violet light and leaching by rain-water.

Dried lumber is rarely shipped without a wrapper unless arrangements have been made to have the wood stored under cover or indoors to prevent wetting. Different wrappers are made from polyethylene (PE) or polypropylene (PP) or PE-PP-kraft paper laminates. Automation of the wrapping process is limited. Research has shown that perfectly applied wrappers are fully effective in preventing ingress of either liquid water or of water vapour when packages are left out in heavy rain. Unfortunately, wrappers often become torn by forklift trucks or by strong winds.

As wrappers may pose disposal problems to the customer (especially laminates, which are more difficult to recycle) water repellents have been proposed as substitutes for wrappers, but research indicates that they are not as effective as lumber wrap in keeping water out of the package. Commercially available water repellents for dry lumber are based on wax dispersions in water; they consequently make the wood more slippery to handle, and may interfere with some remanufacturing operations (e.g., gluing or finishing).

Incremental Technological Innovation

- *Develop and demonstrate environmentally-friendly protection treatments for green and dry lumber.*

4.18 Overall Quality and Process Control

Existing Technology

Quality control programs were developed from the need to maximise volume recovery by decreasing rough green target size. Size control programs were implemented to minimise losses at the planer resulting from significant variations in thickness, and to limit claims. Grade checks were considered to be an integral part of early efforts at quality control.

Almost non-existent ten years ago, quality control is still in its first stages in the sawmilling industry. Today, however, a lower-quality resource base coupled with increasingly quality-conscious customers is forcing producers to look for ways to ensure consistent product quality attributes. The focus is turning to enhanced value recovery, and quality control is becoming a tool to help industry to adapt to a new operating environment.

Very little equipment is available today to carry out process and product control beyond dimension control after sawing, moisture content measurement at the planer, and grading. However, as equipment manufacturers start including process control indicators in their optimising systems (generally equipped with scanners), the way seems to be open for quality and process control all along the manufacturing chain, from bucking to sawing, drying, planing and grading.

Existing systems are primarily designed to optimise manufacturing processes; if these were linked to real time, or continuous monitoring quality control systems to measure and evaluate each piece as it leaves the machine centre, volume recovery would be enhanced because problems would be detected and rectified sooner than might be the case when an individual is responsible for doing periodic size checks. These systems also lend themselves to enhanced value recovery because the greater number of measurements allows for the greater degree of precision required in markets for higher-value products.

Quality monitoring systems also generate detailed information on every piece of lumber produced. This information can be used, not only to ensure that solutions identified by optimisers have actually been realised, but also to detect trends (e.g., tool wear) and trigger intervention before problems happen, thereby minimising waste and down-time. It can also be analysed and used in simulation software to evaluate alternative manufacturing processes or products.

Thus, process control implementation could consist of three stages. The first stage would ensure that the log or lumber is in the right position, and that feed is fully synchronised with tool speed. In the second stage, results (i.e., the product coming out of the machine centre) would be scanned, looped back to the optimiser, and used to refine its decisions. In the third stage, all machine centres would be inter-connected and operated as a single, co-ordinated system.

While mill-wide process control systems are not available today, software programs such as Sawsim and Optitek are already used widely to evaluate manufacturing processes, and to simulate operations. These are powerful management tools, and their use can be expected to spread. The more advanced mills tend to use these programs on their own, while others rely on service providers.

ISO 9000 registration is widely used in Europe and Asia and although it has grown more slowly in North America, it is currently expanding. In Canada, considering the importance of the wood industry in the national economy, the numbers are small compared to other major industries. One of the important benefits of ISO 9000 registration is that it forces a mill management team to study and document processes critical to controlling output. This in turn allows for the development of a culture focused on continuous improvement. Registration is likely to grow in importance as standards for environmental management systems, known as ISO 14000, are introduced.

Incremental Technological Innovation

- *Develop a better understanding of all critical parameters involved in the performance of each machining centre.*
- *Continue developing diagnostic tools to help operators and management optimise quality and process at each machining centre.*
- *Develop tools to compare products obtained to solutions selected by computer programs, and to detect trends.*
- *Develop a better understanding of relationships between the various machining centres, and also between management objectives and machining centre operating criteria.*

Breakthrough Technological Innovation

- *Develop expert systems and computer-based simulators to rapidly transfer innovative technology to sawmill managers and operators, and to optimise decision-making processes.*
- *Integrate on-line quality and process control through mill-wide data flow in order to optimise value recovery on a fully integrated basis.*

4.19 Chipping

Existing Technology

Of the raw material entering the mill, 35 to 50 per cent is converted into chips, which makes it a major economic factor in lumber production. There has, however, been an oversupply of chips for about five years. As a result, prices have been depressed, and the pulp industry has tightened up chip quality requirements. It now demands more uniform chips, with less fines and almost no bark or rot.

Wood chip production is increasingly complicated by the fact that recovery has gone up in the sawmills. There is less whole log chipping to flood chips of a lesser quality. Multiple saw trimmers produce lots of shorts: it would be better if they had a drop fence at the back for whole slash. More drum chippers are likely to be installed in the near future for chipping overs and trim blocks. Modern chipping heads are typically equipped with more knives, and variable drives are used on canters to maintain chip length.

In disk chippers, knife speed is very high in many cases, and this causes the wood to fracture along the grain as it splits off, generating an excess of small chips, pin chips and fines. Similarly, chipper and knife maintenance requirements increase with velocity. Disposable knives contribute to improving chip quality on disk chippers and canters by simplifying tool adjustment and eliminating or reducing grinding. However, some mills are thinking of getting rid of these knives and at least one mill went back to conventional knives, as a result of problems with quality consistency. New technology is available for chip slicing, cracking and screening but its use is essentially limited to pulp mills. Many producers have increased their screening capacity.

Excess fines in chips are frequently caused by the use of wastewood conveyors for removing sawdust. The conventional screens used to separate out the sawdust prior to the wood going into the chipper do not prevent sawdust from sticking to chips which will then carry over the screens to the accepts. Wire mesh screens have a scrubbing action with higher hole-to-surface-area than punch plate screens, and do a better job of removing fines and sawdust; however, the solution is in finding more effective ways of ensuring that sawdust does not enter the wood conveyors.

To meet quality requirements, many mills carry out periodic chip quality control tests. They can then react quickly and improve the chipping process. Chip quality control monitoring is still done manually, samples being analysed on a regular basis with a screen (William's). Artificial vision systems currently under development will provide on-line quality control, but this equipment will probably first be installed in the larger pulp mills. One manufacturer recently released an on-line chip analyser.

Incremental Technological Innovation

- *Design new techniques to produce better quality wood surfaces with chippers and better quality chips.*
- *Develop and implement automatic chip quality monitoring systems.*
- *Devise cost-effective ways of avoiding sawdust contamination of chips.*

4.20 By-product Utilisation

Existing Technology

Apart from chips, the main by-products of the sawmilling industry are sawdust, shavings and bark. Short pieces and trim blocks are increasingly recovered and finger-jointed into high-quality products (see Section 7.3.2 on Finger-jointing). Sawdust and shavings represent the main raw material for particleboard and MDF manufacturers.

In the larger mills, sawdust and planer shavings are mainly used as fuel for energy production. Companies equipped with dry kilns have large energy needs, and wood by-products are an abundant and economical source of fuel. Smaller mills do not have access to wood combustion technology adapted to their needs.

Bark, which represents about 10 per cent of the fibre volume processed by a sawmill, has been an ongoing concern for industry. Traditional methods for bark disposal, like open-air burning and landfilling, have been banned in many regions for environmental reasons. Bark can be used as a fuel, and several companies have been marketing pellets made from bark for domestic heating purposes. In recent years, new applications have appeared, such as soil conditioning and compost (from ground bark) and landscaping (from cedar or hemlock bark, for example), but very large volumes continue to be available, and there is an urgent need to develop major applications. Some companies have explored the production of methanol, ethanol or other chemicals (e.g., "green" phenols); so far however, such projects have generally had difficulty competing with production facilities using natural gas feedstock, pulp waste (black liquor) or even agricultural products.

A panelboard has been developed from bark, and it may hold potential for converting bark into a marketable product. Several on-going scaled-up pilot plant trials are aimed at developing new patented bark board products. These products cover both structural and non-structural applications. Successful commercialisation would lead to a new family of value-added, environmentally-friendly products from bark.

Incremental Technological Innovation

- *Pursue the development of bark boards and other products from bark.*

4.21 Environmental Issues

Existing Technology

Bark disposal remains a major environmental problem for mills that are not equipped with co-generation plants to burn it as hog fuel, many of which still rely on landfills. The disposal of sawmill residue has been a problem since the advent of the sawmilling industry. On the coast of British Columbia, the problem was virtually solved in the 1950s when coastal pulp mills installed boilers designed to use hog fuel. Today, there is a relative balance between the coastal pulp industry's consumption and the coastal sawmilling industry's production of hogfuel. The result is that, while there are periodic imbalances, particularly with respect to cedar hog fuel, there are no beehive burners in coastal sawmills.

Elsewhere, restrictions on beehive burners and open-air combustion in general have created a very awkward situation. In the absence of alternative disposal methods, mills have installed some form of multiple-chambered incineration with emissions scrubbers installed. This involves capital expenditures of $4 to $6 million per sawmill to reach the regulated stacked emission particulate standards. Many mills do not have access to this capital and may be faced with shutting down. Other mills have installed boilers to produce heat for their kilns, but these only use part of their by-products. Clearly there is a need for the development of cost-effective alternatives to current incineration methods, and rising oil prices may provide the right climate for some action.

A number of proposals in the area of co-generation, or wood-fired electrical power production have been brought forward in attempts to deal with the problem. Typically, a sawmill operation can only utilise about one-third of the electrical energy it would produce from its own wood waste. If the mill cannot sell the surplus energy at a reasonable price, the project becomes economically unfeasible. The company attempting to utilise power production to solve the burner problem must deal with a number of factors over which it has little or no control, such as government policies regarding energy pricing, power export restrictions, natural gas prices, and changing demand for electrical energy.

With regard to drying, the industry has had to deal with dehumidification or vacuum drying systems discharging a condensate which generally carries traces of many chemicals naturally occurring in the wood. These are generally the volatile portion of the wood extractives which become a gas in the kiln atmosphere and then condense out with the humidity in the air. Some producers have to buffer the pH of the condensate before discharging it into a sewer or septic system.

Volatile organic compounds (VOCs) emitted by all heat-and-vent and some dehumidification kilns are not regulated at this point. Given that venting occurs through a number of vents, not to mention leaks around doors, any strict regulation of gaseous emissions from kilns would require major physical changes to current kiln design.

Disposal of waste hydraulic oil, which is contracted out to specialised companies, remains an environmental issue for the industry. Hydraulic systems are present in every sawmill. Alternating current drives have replaced hydraulic equipment in some applications, but they are unlikely to become an acceptable substitute in all situations.

Other environmental issues in sawmills include control of dust, noise and vibrations. For many years, equipment manufacturers have been improving machine design to deal with these problems through better enclosures and other devices. Helical planer knives have been used to reduce noise levels. Generally speaking, it has been observed that sharp and well balanced tools operate more quietly (this is particularly true of sawblades); in other words, well maintained tools serve both productivity and environmental objectives.

Countries such as Germany have imposed restrictions on lumber wrappers used to protect dry lumber from moisture; they must be recycled. As measures of this kind become more common, there will be increasing pressure to use only wraps that can be recycled.

Incremental Technological Innovation

- *Continue developing lumber manufacturing equipment with improved features regarding noise and vibrations.*
- *Develop fuel-cells or smaller co-generation units that would allow more mills to produce electricity and sell surplus power back to the grid.*
- *Pursue research on VOC emissions from kilns and methods to minimise such emissions.*
- *Develop cost-effective environmentally-friendly hydraulic oils.*
- *Devise recycling methods for lumber wrappers or effective ways to protect dry lumber without the use of wrappers.*
- *Pursue research on antistain treatments with low environmental impact.*
- *Pursue research to help the wood composites industry utilise a larger portion of sawmilling by-products.*
- *Pursue research to help industry recover increasing amounts of solid wood (shorts, trim, etc.) through remanufacturing and value-added operations.*
- *Pursue development of methods to collect and treat leachates from log yards and other critical areas.*

Breakthrough Technological Innovation

- *Develop a comprehensive strategy to identify commercial applications for bark or its derivatives, and propose a research and development program to create the necessary technology within parameters of economic feasibility.*

CONCLUSIONS FOR THE SOFTWOOD LUMBER INDUSTRY

In conclusion, the Canadian lumber manufacturing industry has been applying new technology at a fairly brisk pace over the past few years, mostly as a result of breakthroughs in computing technology and information management. Many machine centres are equipped with computers, and most medium-to-large mills make use of several optimisers. Programs are available to analyse operations, simulate scenarios and guide management through process or product improvements. Technology gaps have been identified in this section, particularly in relation to the increasing complexity of a modern mill, and to by-product utilisation. Failure to address these shortcomings will restrict the industry's ability to take advantage of changing market requirements.

The main challenge relates to process control, and this is also one of the industry's main opportunities for progress. Not enough information is collected on the results obtained by the various manufacturing functions, and information already available is not used systematically to better control processes. Through the acquisition of more detailed and dynamic information on products in process, and the continuous analysis of this information, manufacturers will be able to reach another level in optimisation. In addition, the databases thus developed will serve as a platform for mill-wide process control. Over the next decade, limitations to progress in this direction are more likely to come from the industry itself than from its suppliers.

Information-based technology requires tools, but, more than anything else, it requires people with the right kind of knowledge. The lumber industry of the 21st Century will need scientists to develop specialised tools, engineers to manufacture and apply them in industry, and operators to work with them on a daily basis. Managers will also need to acquire new skills in areas like marketing, economics and process control in order to function efficiently. It could be said, in fact, that the rate of technological evolution in the lumber manufacturing industry will essentially be determined by its own ability to use it.

In smaller mills and remanufacturing operations, technological evolution will also require knowledge and information-based tools, but these will need to be adapted to the economic and practical circumstances of that sector. Equipment manufacturers and software developers have generally focused on the larger mills, but growth in the remanufacturing and value-added sectors would seem to create a window of opportunity for equipment and programs adapted to their specific needs. It also creates an opportunity for suppliers of services as many of these operations will be unable to maintain all the necessary skills in-house.

5 Hardwood Manufacturing Sector – Existing and Future Technology

The Canadian hardwood lumber manufacturing industry is even more diverse than its softwood counterpart. Whereas much of the softwood lumber production is used in a few building construction applications, hardwood products are used in a broad range of products, from studs (e.g., aspen) or pallets (e.g., low grade birch or maple) to furniture and turnings. The industry is split between mills that tend to borrow technology from softwood lumber mills and produce commodity products, and mills that operate like value-added operations, producing semi-finished products. The technological needs of these two categories are obviously different. This section will concentrate on commodity-type production, while remanufacturing and value-added technology will be covered in later sections.

Another characteristic of the sector is that the different species are treated independently rather than grouped as is the case with many softwoods. As mentioned earlier, aspen and poplars tend to be processed in a similar fashion to spruce and other species used mostly as common building materials.

Most mills continue to operate carriages with circular or band saws. However, most mills now make use of resaws or multiple circular saws to maximise productivity and compensate for the small volume of high quality lumber available from the existing resource base. They typically rely on the operator to make major breakdown decisions. Although optimisation techniques are available to the hardwood manufacturing sector, implementation remains very limited because hardwood mills are relatively small lumber producers. Optimisation is further complicated by the fact that, in the hardwood sector, grade is much more significant than volume, and available optimisers have mostly been developed for volume recovery. Very few of the major producers have added optimised primary breakdown or semi-optimised systems at cant or edging work stations.

Log cost and the lack of quality sawlog material have forced many hardwood lumber producers to look at secondary manufacturing to meet the growing demand for hardwood products. The present trend is to use small-diameter (15 cm [6 inches] and over), short-length logs (1.8 to 2.5 m [6 to 8 feet]) to manufacture products other than those defined by the National Hardwood Lumber Association (NHLA). Short log operations mostly use twin saw headrigs and even chipping headrigs followed by multiple circular resaws to quickly convert small diameter bolts into hardwood components.

Based on the observation that most hardwood applications require only short pieces, some mills have specialised in converting very short logs (down to 1.2 m [48 inches] and even 0.9 m [36 inches]), which has the advantage of broadening their log supply.

5.1 Raw Materials

The Canadian hardwood lumber industry has been competing with other industry sectors for its raw material. While the pulp and OSB industries claim increasing quantities of aspen, poplar and even birch, the better quality logs tend to be selected for veneer production, and the quality of the hardwood resource available for sawing has been deteriorating over the past two or three decades. A common view in the hardwood sawmilling sector is that logs allocated to industry sectors such as composite panels or pulp are "wasted," because such applications do not provide maximum value for the fibre in terms of final products. While recognising that those sectors also have a need for a secure raw material supply, and that the issue of log allocation does not fall strictly under the "technology" mandate of this report, the pursuit of measures likely to enhance the overall value of products derived from the forest appears legitimate wherever feasible.

Integrated companies are in a position to optimise log allocation by running logs through a central yard and sorting them according to quality and diameter category. Other plants resort to log exchanges. Solutions are likely to vary with locations and circumstances, but the trend can be expected to continue as some provincial governments take action to encourage and maximise value recovery and job creation.

Raw material exchanges also provide hardwood mills with an opportunity to escape the dilemma of increasing pallet stock (or other low-value product) volumes as production of high-value products increases.

5.2 Log Bucking, Grading and Allocation

Existing Technology

Hardwood trees are normally bucked into veneer logs (size and quality permitting), sawlogs and pulpwood; but, with the recent trend towards processing short hardwood bolts (15 cm [6 inches] and over in diameter, 1.8 m [6 feet] and over in length), B-1 and B-2 bolt qualities are being recovered for sawing. The part of the stem that does not make lumber is converted into chips for the pulp industry. As stems are delivered to the mill in tree-length form, equipment is needed for slashing and chipping at the mill. On the positive side, this allows producers to maximise log utilisation by sorting them into various quality or diameter categories, taking market opportunities into consideration.

Log grading systems are either developed internally to control the purchase of roundwood from private woodlots or there are provincial grading rules that govern roundwood harvested from crown lands. Harvesting crews grading hardwoods usually rely on a combination of parameters such as log diameter, surface quality and straightness to determine sawlog quality. Hardwood sawlogs are normally bucked on a mobile or fixed slasher according to the operator's evaluation and experience of log quality.

Hardwood mills need to improve their technology and take better advantage of the raw material available in their woodlands; this includes conventional quality logs (according to Petro rules) as well as other logs, referred to as non-conventional quality logs. With non-conventional quality logs, about 50 per cent of the stems could end up in the sawmill, rather than the traditional 35 per cent.

Incremental Technological Innovation

- *Develop tools to assist operators with log allocation and slashing decisions in order to maximise value recovery from individual species.*

Breakthrough Technological Innovation

- *Develop and implement multiple through-the-log scanning technology (x-rays, ultrasounds, radio-frequency, etc., or combinations thereof) to optimise bucking decisions in view of internal and external log characteristics, equipment potential and market opportunities.*

5.3 Log Yard Management

Existing Technology

The primary aim of log yard management is to place the logs into storage so that they can be recovered with minimum damage and at the lowest possible cost. Truck load capacity log stackers are commonly used to handle logs in the yard; they are fast and effective, and skilled operators are generally able to minimise log damage; however, they require that the yard be flat and firm. Log cranes offer high log storage volume per hectare of yard area; they also minimise log damage, but with a single unit typically responsible for the entire inventory, maintenance and downtime issues become critical. Heel boom loaders present a number of advantages, including low log damage, low capital investment, enhanced sorting capability and a tolerance of soft deck areas; these machines, however, are the least productive.

Hardwood mills try to adopt a first-in first-out strategy but this is not always possible due to various constraints pertaining to species or harvesting conditions. Mill managers are increasingly aware of damage and losses associated with infestations by bugs and the impact of dryness and stain on product value and market acceptance. Inventory should thus be rotated each summer to avoid excessive drying and subsequent loss of recovery.

Trees felled with mechanised harvesting equipment are usually damaged in the process, and fungal deterioration is often associated with spiked rollers or with bark damage due to handling or transportation. The increasing cost of logs and the need to maximise value from them is driving the interest in protecting logs from degrade, beginning at the point the trees are cut down. Technology is therefore needed to minimise bark removal and other forms of damage to the logs. Technology is also required to protect logs from fungal attack whenever they need to be stored for more than a few weeks in warm weather.

Incremental Technological Innovation

- *Develop and implement sorting and inventory strategies (including use of log inventory control tools) to reduce lumber recovery losses related to stem damage and fungal degradation in the log yard.*
- *Implement industrial application of integrated bio-chemical log protection treatment to reduce fungal degradation with minimum environmental impact (see softwood section).*

5.4 Debarking

Existing Technology

Most small hardwood mills process 300 to 400 sawlogs per shift and operate "Rosserhead" debarkers. Mills with larger output often have two production lines, with a ring debarker for smaller logs. Debarking quality is usually fairly good but it is not unusual to observe significant damage to log ends. Some species remain difficult to debark, especially in cold weather.

Some short log operations use a drum debarker to debark short hardwood bolts. Debarking quality varies, and significant fibre and lumber recovery losses are incurred due to log damage. Research is needed in the debarking area to investigate means of thawing logs in the winter so as to break the bond between the bark and wood fibres. Studies have been conducted in this area but most, if not all, of the possible solutions identified remain economically inaccessible for the relatively small hardwood lumber producers.

Incremental Technological Innovation

- *Enhance wood quality by eliminating mechanically-induced defects (brown marks) frequently found in the sapwood.*
- *Develop and implement automated debarking quality control systems (e.g., based on artificial vision and image analysis) to check debarked logs for bark presence and damage, to check for wood fibre in bark residue, and to check for bark in chip flow.*
- *Develop cost-efficient and high performance debarking systems for short logs (below 1.8 m [6 feet]).*

Breakthrough Technological Innovation

- *Develop and implement superficial bark thawing systems (e.g., infrared radiation, microwave) as a means of improving debarking quality*

5.5 Primary Breakdown

Existing Technology

High Value Sawn Products

For higher-value species, such as maple, oak, birch and alder, the primary breakdown is performed on a carriage either with a single- or double-cut bandsaw. An operator aid is usually available to assist in the breakdown sequence but all of the quality decisions are operator-driven. Non-conventional logs (i.e., small diameter or length under 2.4 m [8 feet]) are usually processed on an overhead carriage with an end-dogging system which holds the logs through a twin circular or a twin bandsaw headrig followed by a multiple circular resaw. High productivity is very important as these small logs offer little high-value lumber; for this reason, manufacturers go further in the manufacturing process and produce higher-value components rather than low-value lumber.

More advanced systems use scanning and optimisation systems either on a carriage (light curtain) or an end-dogging twin headrig with double-axis scanning to maximise product volume and value recovery. These systems are expensive and require qualified maintenance personnel; consequently very few hardwood sawmills can economically justify their installation.

Optimisation in hardwoods has to go one step further than is the case in softwood mills. In addition to the log positioning, log rotation and breakdown optimisation, hardwoods require that defect size, type and location on the log be an integral part of the optimisation process. Internal log scanning to determine defect location would be ideal but, given the size and quality of the hardwood resource processed, it is doubtful that such equipment would be economically justifiable by sawmills that have limited production capabilities.

Commodity Products

Aspen and poplar species are usually processed through sawmills using technology similar to that used in softwood lumber production, at least when the end products are studs or dimension lumber for building construction. Conversion practice, however, is related to the type of end-product rather than to the species, and it is not uncommon for aspen or poplar to be converted into components, in which case they would be processed in exactly the same manner as the "high-value" species.

Incremental Technological Innovation

- *Develop and implement cost-effective optimisation systems for edging and trimming based on the same concepts as those used in, or suggested for, the softwood lumber industry.*
- *Develop and implement cost-effective product monitoring systems to provide quality control and feedback.*
- *Develop technology to process shorter (less than six feet, down to three feet) quality lumber for manufacturers who do not need longer raw material or for finger-jointing.*
- *Process lower grade logs into lumber that can be repaired at a later stage.*

5.6 Secondary Breakdown of High-value Lumber

Existing Technology

The secondary breakdown is performed through circular or band resaws with a merry-go-round enabling the resaw operator to process the lumber pieces more than once in order to maximise value recovery. Mills with smaller, lower quality logs operate multiple circular resaws to ensure maximum productivity. Most are fed manually by the operator.

Some mills operate multiple circular resaws but with saws mounted on a telescopic arbor which offers more flexibility as the saw banks can shift to produce a higher quality product mix whenever possible. The more advanced systems use scanning to determine cant shape while the operator provides information on cant quality, and both sets of data are integrated to optimise cant position and breakdown pattern.

Incremental Technological Innovation

- *Provide decision-aids and training programs for operators and middle management to optimise the secondary breakdown process. This could include scanning equipment and software to compute the best solutions.*
- *Adapt thin-kerf circular saw technology to headrigs and multiple resaws.*
- *Adapt or develop handling technology suitable for short pieces.*

Breakthrough Technological Innovation

- *Develop and implement cost-effective through-the-log scanning systems to determine the type and the position of defects (including internal defects) as well as cant shape so as to maximise product value from cants.*
- *Optimise the secondary breakdown process through integrated product and process monitoring and feedback.*

5.7 Lumber Sorting and Grading

Existing Technology

A majority of hardwood mills rely on certified graders to grade and tally the lumber. In smaller mills, lumber tally and grade out-turn are recorded by the grader himself; mills with greater output use a separate grader and tally-man. Only a few mills have installed computerised systems to stamp the lumber according to the grader's decision, and to compile production statistics (e.g., board footage and piece count) and to indicate to lumber stackers when it is time to strap the bundle and start a new one.

Sorting hardwood lumber is relatively easy as the lumber is either marked or stamped by the grader. The major challenge relates to stacking, which is still performed manually and requires several people. In many mills, the stacking operation is semi-automated; however, random lengths ranging from 1.2 to 4.9 m (4 to 16 feet) in random widths remain difficult to fit in regular package specifications (dimensions and volume content). It is also difficult for a mechanised system to "understand" that short lumber lengths have to be matched and placed end to end to produce a square bundle. Random widths also make it difficult to end up with a specific package size without exceeding the board footage content of a given bundle.

Incremental Technological Innovation

- *Adapt or develop automated lumber sorters and stackers capable of producing square bundles for drying lumber in random lengths and random widths.*
- *Develop and implement hardwood grading systems based on automatic vision. Depending on mill circumstances, these could be semi-automatic (decision-aids) or fully automatic.*

Breakthrough Technological Innovation

- *Develop an integrated automatic system using multi-sensing devices to scan and grade hardwoods.*

5.8 Drying

This section deals primarily with hardwoods; however, since white pine and ponderosa pine are processed in many of the same mills that produce hardwoods and with the same equipment and techniques, they will also be covered. Hardwood drying is conducted mostly at the sawmills and some custom dryers. A small percentage of material is dried by end-users. There are very few vertically integrated companies starting with the log and producing a consumer product, so that feedback is limited even though end-user specifications are critical with respect to average final moisture content and also moisture gradient, stress condition, presence of checking (internal and external), warpage, and discoloration.

Aspen, poplar and white pine frequently contain "wetwood." Wetwood occurs randomly within a tree, and it is believed to be the result of bacterial infection. Wetwood zones dry much more slowly than normal wood, and often result in wet pockets within otherwise dry boards.

5.8.1 Piling, Handling and Air Drying

Existing Technology

Most piling in hardwood mills is accomplished either fully manually or with semi-automated stacking systems. Manual piling operations are usually conducted in open sheds with sticker guides. Semi-automated piling involves using two or three labourers, a tilt hoist, transfer chain area to arrange boards, and a stacker. Stickers are laid either automatically or manually. In either case, labourers physically arrange the boards to ensure proper placement within a row.

Stickers are placed at a spacing of 30 to 60 cm (12 to 24 inches). Stickers are typically made of hardwood, however, a number of alternative materials, including plastic composites and metal, have been introduced, with limited success, to minimise the contact area between the sticker and the board, and to avoid discoloration. Most mills producing light-coloured hardwoods are using some sort of profiled sticker.

Due to the relatively long drying times and material flow from the sawmill, most drying operations find it necessary to conduct some air drying. Air drying yards have been the source of problems for many operations over the years as it is often difficult to avoid slow drying conditions that can cause stain. The current trend is to avoid placing sapstain-sensitive material in an air drying yard or to set up air drying yards to promote more rapid drying.

Incremental Technological Innovation

- *Develop lumber stackers capable of piling lumber of short and mixed lengths into standard square bundles.*

- *Devise stickers and stickering methods to minimise sticker discoloration of light-coloured hardwoods.*
- *Develop cost-effective methods to protect hardwood lumber from stain during air-drying.*
- *Develop drying methods that do not require stickering.*
- *Develop methods to separate wetwood from regular material prior to drying, in order to optimise drying time and quality.*

5.8.2 Drying Equipment and Control

Existing Technology

The traditional means of drying in this industry has been with steam-heated, heat-and-vent kilns, often referred to as conventional kilns. These kilns typically operate at temperatures up to 80°C (180°F) and are equipped with venting and humidification systems. Drying time can vary from five or six days for low-density, 25-mm (one-inch) thick hardwoods to 60 days and longer for high-density, 50-mm (two-inch) thick stock. Virtually all kilns installed within the past 20 years have been of aluminium panel construction with a steel or aluminium beam supporting structure. The batch-loaded kilns are usually side-loaded by forklift with a small percentage of operators opting for a track-loading configuration. Air flow is achieved by internally mounted fans.

The past 15 to 20 years have seen a diversification of kiln types with this trend likely continuing for the next few years. Dehumidification drying was introduced into North America in the 1970s and has gone through several evolutionary phases. Its initial appeal was lower energy consumption and reliance on electricity at a time when fossil fuels were continually rising in price. Since then, it has found a niche with the hardwood and white pine producers, especially small- to medium-size operations, largely because they can build their own enclosure to reduce capital costs. The drying temperatures employed in most units now approach those in conventional, heat-and-vent kilns and therefore drying times are only slightly longer.

Air flow requirements are similar for both heat-and-vent and dehumidification kilns. Slower drying hardwoods will require 90 to 120 metres (300 to 400 feet) per minute, faster drying hardwoods 150 metres (500 feet) per minute and specialty products such as sap maple and white pine up to 210 metres (700 feet). Adjustable speed drives to vary air flow are common in newer installations.

The main challenge for operators of heat-and-vent or dehumidification kilns is to avoid drying defects. This is generally achieved by close monitoring and control of the material rather than through specialised operation of the drying equipment.

Vacuum drying has started to emerge as a viable alternative for hardwood drying operations. Vacuum kilns have existed in Europe for many years but not made a significant inroad into North America until recently. Recent advances in the technology and changes in the wood industry appear to offer an opportunity for such systems. The two forms of vacuum drying receiving the most attention at this time are superheated steam/vacuum (SS/V) and radio-frequency vacuum (RFV). As the name implies, SS/V kilns utilise steam to transfer heat to the wood; the steam is generated from moisture released from the drying wood, rather than injected into the kiln. In RFV drying, the lumber is continually heated through exposure to radio-frequency waves.

A major advantage of the vacuum drying technology stems from shorter drying times and lower operating temperatures. Drying times for an SS/V kiln are typically one-third or less of the time required in a heat-and-vent kiln. A RFV kiln may reduce drying time to 1/17th of the heat-and-vent time. The lower operating temperatures result in less thermal darkening of the wood, and the absence of oxygen can block various chemical stains in the wood. In addition, RFV kilns can dry mixed lumber thicknesses without stickering. They have also proved capable of drying wetwood-prone species effectively. The major hurdle to be overcome by vacuum drying appears to be the development of a database on drying of North American species. Such a database will identify specific operating routines for various products and instil a degree of confidence in potential users.

Virtually all hardwood drying operations (and many processing white pine) use a manual, sample board technique to monitor the progress of drying and make decisions on kiln conditions. The two principal alternatives to sample boards are moisture content probes and automatic weighing systems. Moisture content probes are based on DC-resistance measurements continually made on various samples scattered around the load. Due to the inherent variability and limited accuracy of DC-resistance readings, these controllers are typically found in operations that also employ manual sample boards. Automatic weighing systems, on the other hand, offer a complete replacement for the manual sample board system; their major disadvantage at this time appears to be cost. Handheld meters are used extensively for final moisture content determination to supplement the information gathered for kiln control, but these are awkward to use in a kiln environment, and prone to error.

Incremental Technological Innovation

- *Investigate techniques likely to improve temperature uniformity in direct-fired kilns (new and retrofit).*
- *Optimise application of adjustable speed fans.*
- *Provide reliable calibration procedures or correlations between on-line moisture meters, hand-held resistance meters and hand-held DC-resistance meters so that all moisture content measurements in the mill may be comparable and usable in common databases.*
- *Develop and implement methods to accurately measure the moisture content of frozen lumber.*
- *Develop instruments and tools for the on-going (direct or indirect) measurement of actual drying rate in the kiln. Given the size of the kilns, this will likely require a number of sensors measuring temperature (dry- and wet-bulb) in various locations, wood mass and moisture content, and possibly some other indicators or combination of indicators with a strong correlation to drying rate and water extracted.*
- *Pursue modelling activities as a tool for more efficient kiln control.*
- *Develop and implement methods to monitor kiln-dried lumber for drying defects (checking, warp, etc.) in real time and to analyse this information for kiln control.*
- *Optimise drying schedules for stress relief (use of humidification).*
- *Apply feedback from grading system as input for kiln control and drying quality control.*
- *Evaluate kiln characteristics (and related costs) in relation to expected results, and develop practical recommendations.*
- *Continue development work to adapt SS/V and RFV drying to a broader range of industrial applications.*

Breakthrough Technological Innovation

- *Develop and implement a kiln controller capable of integrating load input (lumber mass and size, lumber moisture content average and distribution, lumber temperature, species, pile characteristics, and "dryability" information), kiln characteristics, energy input, air flow characteristics, and production objectives (product quality, etc.).*
- *Develop and implement an integrated method to analyse all data pertaining to kiln-dried lumber production and relate it back to information collected at the dryers and at the sorting station in order to optimise sorting and drying strategies.*

5.8.3 Discoloration Due to Drying

Existing Technology

Issues related to colour have come to the forefront over the past 10 years or so, mostly as a result of a move toward lighter stains or no stain at all on wood used in appearance applications such as flooring and furniture.

There two categories of discoloration: those that are related to fungal activity in the wood (sapstain) and those that are a consequence of reactions between chemicals naturally occurring in the wood (chemical stains). Sapstain was discussed earlier, in Section 5.8.1 on Piling, Handling and Air-Drying. Chemical stains cannot be controlled with treatments and are more difficult to avoid than sapstain. Many of them are very subtle in nature and may not be noticed until the wood has been dried and planed.

Hard maple is one of the major hardwood species produced in Eastern Canada. It is currently in demand because of its light colour and durability. Unfortunately, hard maple is prone to a number of chemical discolorations such as sticker stain and interior greying. Research carried out in the early 1990s demonstrated the complex chemistry involved in the staining mechanism but was unable to identify an effective treatment to eliminate it. Sticker stain and other chemical stains in maple are believed to be caused by a similar mechanism and together cause millions of dollars in losses to the industry.

White pine is susceptible to a chocolate-brown discoloration known as "brown stain" or "kiln burn." This stain is biological or bio-chemical in nature and is also responsible for considerable monetary loss to the industry. Many mills only cut white pine during winter months as a means of avoiding this stain. There is no treatment to effectively protect against brown stain at all times of the year.

Incremental Technological Innovation

- *Investigate staining mechanisms in hard maple and other high-value hardwood species, and develop solutions.*
- *Investigate brown stain discoloration mechanism in white pine, and develop solutions.*

5.9 By-product Utilisation

Existing Technology

Apart from chips, the main by-products of the sawmilling industry are sawdust, shavings and bark. Short pieces and trim blocks are increasingly recovered and finger-jointed into high-quality products (see Section 7.3.2 on Finger-jointing). Sawdust and shavings are frequently used as raw material by particleboard and MDF manufacturers.

In the larger mills, sawdust and planer shavings are mainly used as fuel for energy production. Companies equipped with dry kilns have large energy needs, and wood by-products are an abundant and economical source of fuel. Smaller mills do not have access to wood combustion technology adapted to their needs.

Bark, which represents about 10 per cent of the fibre volume processed by a sawmill, has been an ongoing concern for industry. Traditional methods for disposing of bark, like open-air burning and landfilling, have been banned in many regions for environmental reasons. Bark can be used as a fuel, and several companies have been marketing pellets made from bark for domestic heating purposes. In recent years, new applications have appeared, such as soil conditioning and compost (from ground bark) but very large volumes continue to be available, and there is an urgent need to develop major applications. Some companies have explored the production of methanol, ethanol or other chemicals (e.g., "green" phenols); so far however, such projects have generally had difficulty competing with production facilities using natural gas feedstock, pulp waste (black liquor) or even agricultural products.

A panelboard has been developed from bark, and it may hold potential for converting bark into a marketable product. Several on-going scaled-up pilot plant trials are aimed at developing new patented bark board products. These products cover both structural and non-structural applications. Successful commercialisation would lead to a new family of value-added, environmentally-friendly products from bark.

Incremental Technological Innovation

- *Pursue the development of bark boards and other products from bark.*

5.10 Environmental Issues

Existing Technology

Bark disposal remains a major environmental problem for mills that are not equipped with co-generation plants to burn it as hog fuel, many of which still rely on landfills. Restrictions on beehive burners and open-air combustion in general have created a very awkward situation. In the absence of alternative disposal methods, mills have installed some form of multiple-chambered incineration with emissions scrubbers installed. This involves capital expenditures of $4 to $6 million per sawmill to reach the regulated stacked emission particulate standards. Many mills do not have access to this capital and may be faced with shutting down. Other mills have installed boilers to produce heat for their kilns, but these only use part of their by-products. Clearly there is a need for the development of cost-effective alternatives to current incineration methods, and rising oil prices may provide the right climate for some action.

A number of proposals in the area of co-generation, or wood-fired electrical power production have been brought forward in attempts to deal with the problem. Typically, a sawmill operation can only utilise about one-third of the electrical energy it would produce from its own wood waste. If the mill cannot sell the surplus energy at a reasonable price, the project becomes economically unfeasible. The company attempting to utilise power production to solve the burner problem must deal with a number of factors over which it has little or no control, such as government policies regarding energy pricing, power export restrictions, natural gas prices, and changing demand for electrical energy.

With regard to drying, the industry has had to deal with dehumidification or vacuum drying systems discharging a condensate which generally carries traces of many chemicals naturally occurring in the wood. These are generally the volatile portion of the wood extractives which become a gas in the kiln atmosphere and then condense out with the humidity in the air. Some producers have to buffer the pH of the condensate before discharging it into a sewer or septic system.

Volatile organic compounds (VOCs) emitted by all heat-and-vent and some dehumidification kilns are not regulated at this point. Given that venting occurs through a number of vents, not to mention leaks around doors, any strict regulation of gaseous emissions from kilns would require major physical changes to current kiln design.

Disposal of waste hydraulic oil, which is contracted out to specialised companies, remains an environmental issue for the industry. Hydraulic systems are present in every sawmill. Alternating current drives have replaced hydraulic equipment in some applications, but they are unlikely to become an acceptable substitute in all situations.

Other environmental issues in sawmills include control of dust, noise and vibrations. For many years, equipment manufacturers have been improving machine design to deal with these problems through better enclosures and other devices. Helical planer knives have been used to reduce noise levels. Generally speaking, it has been observed that sharp and well balanced tools operate more quietly (this is particularly true of sawblades); in other words, well maintained tools serve both productivity and environmental objectives.

Incremental Technological Innovation

- *Continue developing lumber manufacturing equipment with improved features regarding noise and vibrations.*

- *Develop fuel-cells or smaller co-generation units that would allow more mills to produce electricity and sell surplus power back to the grid.*
- *Pursue research on VOC emissions from kilns and methods to minimise such emissions.*
- *Develop cost-effective environmentally-friendly hydraulic oils.*
- *Pursue research on antistain treatments with low environmental impact.*
- *Pursue research to help the wood composites industry utilise a larger portion of sawmilling by-products.*
- *Pursue research to help industry recover increasing amounts of solid wood (shorts, trim, etc.) through remanufacturing and value-added operations.*
- *Pursue development of methods to collect and treat leachates.*

Breakthrough Technological Innovation

- *Develop a comprehensive strategy to identify commercial applications for bark or its derivatives, and propose a research and development program to create the necessary technology within parameters of economic feasibility.*

Conclusions for the Hardwood Lumber Industry

In conclusion, the hardwood lumber industry's future will depend to a large extent on its ability to process a broader variety of logs, both in terms of size and quality, into a diversity of products. The technology needed to improve quality and recovery is similar to that identified for the softwood sector (i.e., process optimisation, product monitoring, sorting and grading systems, etc.). Equipment designed for the hardwood sector needs more capabilities in terms of defect and grade recognition. In most cases, however, volumes are limited and the plants do not have the necessary financial resources, so that full automation may not be economically feasible. Emphasis will therefore be on decision-aid tools for operators. With respect to machinery, opportunities seem to exist to adapt equipment used in the softwood sector; again, the challenge will be to do so in a cost-effective manner. Many hardwood mills can be expected to move further into value-added production.

As in the softwood sector, process control represents a major challenge as well as one of the industry's main opportunities for progress. Not enough information is collected on the results obtained by the various manufacturing functions, and information already available is not used systematically to better control processes. Through the acquisition of more detailed and dynamic information on products in process, and the continuous analysis of this information, manufacturers will be able to reach another level in optimisation. In addition, the databases thus developed will serve as a platform for mill-wide process control. Over the next decade, limitations to progress in this direction are more likely to come from the industry itself than from its suppliers.

Information-based technology requires tools, but, more than anything else, it requires people with the right kind of knowledge. The lumber industry of the 21st Century will need scientists to develop specialised tools, engineers to manufacture and apply them in industry, and operators to work with them on a daily basis. Managers will also need to acquire new skills in areas like marketing, economics and process control in order to function efficiently.

In smaller mills and remanufacturing operations, technological evolution will also require knowledge and information-based tools, but these will need to be adapted to the economic and practical circumstances of that sector. Equipment manufacturers and software developers have generally focused on the larger mills, but growth in the remanufacturing and value-added sectors would seem to create a window of opportunity for equipment and programs adapted to their specific needs. It also creates an opportunity for suppliers of services as many of these operations will be unable to maintain all the necessary skills in-house.

6 Softwood and Hardwood Value-added Products

Many sawmills seek to diversify markets and add value to their products by remanufacturing commodity lumber into a variety of products, ranging from simple lath to fairly complex mouldings. By integrating these operations into their regular manufacturing and marketing operations, they are in a position to add value to their output without unduly increasing costs. Even though value-added products are seen by many in the industry as the way of the future, the challenge for most remains one of addressing niche markets without jeopardising economies of scale.

Independent remanufacturing plants purchase lumber from sawmills, and add value to it through a variety of operations, including ripping, cross-cutting, moulding and re-grading. In many cases, they rely on low-grade lumber as a raw material, and their access to sophisticated equipment is limited by scant financial resources.

The value-added sector includes all secondary wood products manufacturers that add value to commodity wood products by further processing them into specialty finished or semi-finished products:

- remanufactured products (lumber specialties, fencing, etc.),
- engineered wood products (MSR lumber, laminated beams, trusses, wood I-beams, etc.),
- millwork (doors, windows, architectural woodwork, turnings, etc.),
- cabinets (kitchen and vanity cabinets, cabinet doors, countertops, etc.),
- furniture (household furniture, ready-to-assemble furniture, commercial and institutional furniture, patio furniture, etc.),
- pallets and containers, and
- other wood products (chopsticks, ladders, etc.).

Custom drying operations or pre-cutters (who cut components for specific clients) are usually classified in the remanufacturing group.

The technology employed in remanufacturing and many other secondary manufacturing operations is similar to that used in regular sawmills in terms of scanning, ripping, cross-cutting, etc., and many technology opportunities previously discussed also apply to this sector. Other operations commonly practised in the value-added sector (specialty drying, gluing, shaping, finishing, etc.) are discussed in Section 7, Engineered Wood Products, or in Section 8, Appearance Wood Products. Preservative-treated wood products are discussed in Section 9.

7 Engineered Wood Products – Existing and Future Technology

7.1 Introduction and Overview

Engineered wood products (EWP) are not a new concept. The rearrangement of wood with the assistance of an adhesive has been with us for over a century as an industrial, proven concept—plywood. Laminated beams were first assembled with nails, then with adhesives. Trusses, originally assembled with nails, experienced phenomenal growth, starting half a century ago with the assistance of steel plates. While original engineered wood products were initially designed to replace traditional wood products (panel products for planks, laminated beams for large sections), engineers soon realised that they could make use of their new-found flexibility to design systems making better use of available resources while providing products better suited to market demand.

This section will focus on non-panel engineered wood products, made mostly from small sections of high-performance wood, and assembled according to recognised engineering principles to provide the most efficient match between the forest resource and specific needs of the building industry for high-performance structural products. The products described include machine stress-rated (MSR) lumber, finger-jointed lumber, glued-laminated ("glulam") lumber, wood I-beams and metal-plated trusses. Composite panel products will not be discussed in this report, as they were covered in detail in a separate Roadmap. This report will also exclude engineered products such as Parallam[1] and Parallel Strand Lumber (PSL)[1], which are proprietary products manufactured from wood strands, and laminated-veneer lumber (LVL), which is manufactured from veneer.

7.2 Industry Vision and Driving Forces

Demand for engineered wood products has grown dramatically over the past ten years, and it is growing at the rate of 250 million board feet (equivalent) per year in the US alone. While the uninterrupted economic boom over the same period has clearly had a favourable effect on such growth, the industry sees it as driven by a number of underlying forces, and expects its progression to continue.

In all Canadian regions other than the Pacific Coast, growth in this industry sector has been led by changes in ***resource characteristics***. Trees harvested have been getting smaller as a result of shorter rotations and other factors. Engineered wood products offer the wood industry a unique opportunity to use and add value to smaller, lower-quality logs. In some cases, they allow structural applications for under-utilised, non-traditional species, including aspen and plantation trees (hybrid poplar). As a result, the Canadian wood industry has seized on this opportunity, especially in Alberta and Eastern Canada (where logs are smaller), and engineered wood products have become the fastest growing sector of the industry.

Like all remanufacturing and value-added activities, the manufacturing of engineered wood products has been encouraged by governments at all levels, because of their potential for ***optimum resource utilisation, job creation and export potential***. In view of the issues affecting the industry's future, including raw material availability, skilled labour availability, research and development requirements, etc., and given the fact that much of the industry will continue to consist of small and medium companies, ***government commitment and support*** can be expected to be critical.

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[1] Brand name belonging to Trus Joist

The imposition of a ***quota*** on Canadian softwood lumber shipments to the US has motivated an increasing number of mills to move into the production of engineered wood products and systems, or other new value-added wood products. Under the quota system, mills tend to maximise the value of their lumber exports by concentrating on higher grades. Lower grades are therefore available locally for remanufacturing and value-added production. In the future, the quota system may be replaced by a different arrangement, and the value-added sector sees this as a threat as it may reduce its access to affordable lumber. However, whether the quota is maintained or replaced by some form of "free" trade, it appears likely that the incentive to add value to wood products at source, or close to it, will remain.

High lumber prices are a boost to growth in the engineered wood product sector, as they tend to encourage substitution. While high prices obviously open the door to steel and other non-wood substitutes, they have been a major factor in the acceptance of engineered wood products, which were traditionally more costly. This is not the place to speculate over fluctuations in the North American economy over the next decade, and lumber prices will most likely reflect such fluctuations, but it is safe to assume that, on the whole, the wood supply will continue to be restricted, and prices will generally remain on the high side, favouring engineered substitutes.

Architects, engineers and builders appreciate the ***quality and reliability*** of engineered wood products. Individual components used to manufacture them are checked to ensure that they possess adequate physical and mechanical properties before being admitted into the production process. Quality control is strict and products are normally subjected to third-party certification. Design values of engineered wood products are precisely known, and variations limited. Every piece meets agreed specifications, with no rejects at the building site. To maintain an acceptable level of reliability, the industry will need to develop more detailed knowledge of its raw materials, including ***specific properties of individual species*** (as opposed to conventional species groups).

Engineered wood products can be ***designed to meet the specific and changing requirements*** of the building industry and building owners (e.g., longer spans, reduced building time). Selling prices may be higher than for conventional lumber, but installed unit costs tend to be lower, especially in the complex structures demanded by today's markets.

Over the years, all materials have evolved, and so have building techniques. The increasing use of ***prefabricated building systems*** on building sites also favours the selection of pre-engineered components designed for easy installation, and this trend has been reinforced by a ***shortage of skilled building construction labour***.

To take advantage of market opportunities and to develop the right products at the right time, the industry will require ***sophisticated market knowledge*** of the type used in consumer products, including consumption trends, evolution of distribution systems (e.g., e-commerce), and required attributes.

While this document discusses evolving technology in connection with existing engineered wood products, their very nature makes them an ideal conduit for ***innovation***, and new products are being developed at an accelerating rate. Engineered wood products represent the wood industry's best strategy to maintain market share in residential construction, increase it in commercial construction, and expand export markets by delivering better value to end-users in a competitive world. In the current climate, innovation can be expected to continue and to play a critical role in the Canadian wood industry's success. However, successful innovation will need to take place in a context of ***market-driven building systems development***.

To maintain market share in the face of aggressive competition from steel and concrete, and to penetrate markets where wood is not a traditional building material, the wood industry needs to create and promote ***design options*** and ***system performance attributes*** which are not necessarily associated with wood itself: durability, fire resistance, resistance to extreme loads, or ease of installation This implies the development of innovative products as part of innovative systems. This essential issue goes beyond the scope of the present report, but it deserves to be covered in a separate study, and a recommendation to this effect is included in Section 11.

While design is the key to new products, existing products will maintain market share through ***enhanced cost-competitiveness*** and adoption of state-of-the-art technology to reduce production costs. This will rely on the development of decision-aids and cost-effective approaches to automation.

Because engineered wood products are used in structural applications, they have to meet strict code requirements and approval procedures. As these have traditionally been built around conventional products, they can prove extremely difficult and costly for new products and systems, in spite of efforts by various organisations to solve the problem of ***market access***. The problem becomes even more serious in overseas markets, where the cost of securing all the necessary documents reaches far beyond the capabilities of most producers.

Because EWP are used in structural applications, their continuing growth is dependent on the ***availability of advanced engineering skills***, not only in manufacturing, but also in research and development, and in marketing the products.

Overall, the industry sees itself in a very optimistic light, with almost unlimited potential in the US and elsewhere, and there is every reason to believe that such enthusiasm is supported by reality. In the final analysis, however, its continued success will depend on its ability to maintain momentum through dynamic market knowledge and advanced technology, and to turn these into market value.

7.3 Major Engineered Wood Products

This section reviews major engineered wood products and issues specific to them, while the next section (7.4) discusses technological issues common to most engineered wood products.

7.3.1 Machine Stress-rated Lumber

Machine stress-rated lumber (MSR) is dimension lumber that has been evaluated by mechanical stress-rating equipment. The stress-rating equipment measures the stiffness of the material and sorts it into various modulus of elasticity (MOE) classes. Research has shown that a direct correlation exists between the bending stiffness of a piece of lumber, its density, its bending strength or modulus of rupture (MOR), and its ultimate tensile strength.

MSR lumber differs from visually stress-graded lumber in that each piece is non-destructively evaluated for bending stiffness. It allows designers to reduce safety factors in their calculations without increasing the risk of failure. At this time, much of the MSR production is used in the manufacturing of I-joists, roof and floor trusses, because these are sectors of the industry that demand economic and structural efficiency from the materials they employ. MSR grading obviously presents the highest potential for species like black spruce, lodgepole pine and other slow-growth, high-density species from the boreal forest, since it recognises their superior properties. For this reason, a number of sawmills are producing this product and more can be expected to follow.

The first Canadian mechanical lumber grading machine was installed in BC in 1976. Today MSR lumber is commonly used so that material of higher strength can be segregated more readily than through visual grading. Two types of machines are used in strength prediction: one based on evaluating the bending stiffness, the other based on measuring wood density (this is usually referred to as mechanical evaluation of lumber, MEL). Both machines are used simply to sort the pieces into categories (grades) that are predicted to have similar mechanical properties.

Machine stress-rating does not replace visual grading because visual graders are still required to override machine decisions when the lumber does not meet allowable visual defect requirements. In

North America the production of MSR lumber relies on qualification at the mill level (that is, machine settings for sorting the lumber are mill-specific) and ongoing quality control testing to verify the strength and stiffness properties of the final product. As discussed in Section 4.16 on softwood lumber grading, scanning equipment is now available to consistently and accurately measure wane and other geometry-related defects, and research is continuing on vision systems for knot, decay and other defect recognition.

Commercial lumber evaluation methods are very efficient tools to grade conventional lumber for structural applications, especially those using wood in bending. Design values assigned to the lumber for tension, compression or shear, for example, were derived from in-grade tests, but they are not optimised for every piece of lumber. As specifications for lumber products multiply, other types of grading will become necessary. Research is continuing on alternative methods to evaluate wood and wood products from the combined points of view of mechanical performance and appearance. See also 7.4.6, Quality & Process Control.

Since machine-graded lumber is drawn from lumber that would otherwise be sold as visually-graded lumber, any pre-sorting or upstream changes that serve to improve MSR recovery would be beneficial.

Incremental Technological Innovation

- *Develop and implement MSR optimisation systems, such as Forintek's MSR Toolkit, which allows users to optimise grade recovery by analysing results obtained by the grading machine with the mill's lumber.*
- *Develop and implement scanning systems capable of predicting MSR potential in logs (see Section 4.6).*
- *Develop and implement cost-effective systems to sort lumber for species, density, moisture content and other characteristics prior to MSR grading.*

Breakthrough Technological Innovation

- *Implement multi-sensor scanning systems based on image processing technology to detect non-geometric defects in lumber so as to eliminate the need for visual grading. Such systems should be adaptable to a variety of machine centres and client specifications.*
- *Develop methods and devices to better predict the ultimate strength of tension, bending, shear and compression.*

7.3.2 Finger-jointed Lumber

Finger-jointing is a wood processing technique that consists of cutting finger profiles into the ends of wood pieces, and joining them into longer pieces with an adhesive. The finger-jointing process began in the United States in the 1920s, and was mainly used in the automobile industry. It was later adopted by the glulam industry to replace the more wasteful scarf joint. Finger-jointing has now become a way to convert short wood lengths and low-grade lumber into high-performance and high-value products.

Finger-jointed material for both structural and non-structural uses is now commonly produced by the lumber industry and well accepted by the building industry and by trade organisations associated with these industries. This section will focus on structural finger-joints, while appearance joints will be covered in Section 8. In some instances, finger-jointed lumber is actually preferred to solid, unjointed lumber because of its superior stability.

The potential strength or performance of a finger-joint is an interdependent function of the slope, the pitch, the finger length and the tip thickness. Ideal joints of maximum strength are difficult to produce economically in wood but as the tip approaches zero, and the slope and length are such as to provide an adequate effective glue joint area, joint strength will approach the tensile strength of solid wood (around 90 per cent).

There are three main types of structural finger-joints: vertical, horizontal and inclined at 45 degrees. Vertical finger-jointing (fingers cut parallel to the narrow face) is mainly used in Europe and permits operating the finger-jointing process at up to 60 blocks per minute, while horizontal jointing (fingers cut parallel to the wide face) is used in North America and permits 60 to 140 blocks per minute. Under normal production conditions, the vertical profile is generally stronger than the horizontal profile and it is used for glued laminated timbers; while the horizontal profile tends to be used for finger-joined lumber.

While finger-jointing is most commonly performed on dry material, there are economic advantages to jointing blocks in the green state: increased value for trims blocks; reduced chip production; higher product value for low-grade material; and more efficient use of kilns (medium temperature). With modern adhesives technology, it is possible to finger-joint pieces of lumber with moisture contents up to 180 per cent. It is even possible to finger-joint dry and wet pieces, whether or not they are frozen.

7.3.2.1 Raw Material

Existing Technology

Raw materials for finger-jointing are generally dry trim ends from the planer mill. Given current fibre supply constraints and waste disposal issues, green trim ends also represent a valuable resource base if they can be put to a better use than hog fuel or chips. Finger-jointing is typically performed on softwood lumber since hardwood lumber is hardly used in North America for structural building components other than composites. Hardwood could, however, be used in I-joists since it could provide superior tensile performance in the lower flange.

Incremental Technological Innovation

- *Develop cost-effective techniques to manufacture vertical joints in green and dry lumber.*
- *Adapt structural finger-jointing techniques to hardwood lumber, and have them accepted in the relevant standards.*
- *Develop and implement non-destructive evaluation techniques to grade short lumber pieces so they could be sorted out and assembled with other pieces of the same strength, thereby yielding a higher proportion of high-strength lumber. Other sorting criteria could include dimensional stability (e.g., compression or juvenile wood, excessive slope of grain), moisture content, etc.*

7.3.2.2 Material Handling

Existing Technology

Feeding blocks to the machine currently requires one or two operators, and stacking the boards at the outfeed requires one operator. Automatic feeders are used to place the blocks on the lugs to increase productivity. The trend in a number of mills has been to joint ever shorter blocks as lumber value increases and chip value decreases; this will further complicate the task of automating handling operations, but makes it even more necessary if productivity is to be maintained.

Incremental Technological Innovation

- *Develop and implement semi-automatic or automatic infeed and outfeed systems capable of handling short blocks fast enough to make full use of jointer production capacity.*
- *Develop new methods to facilitate or automate machine set-up time. This will become even more critical when the infeed process is automated.*

7.3.2.3 Block Preparation and Finger-joint Shaping

Existing Technology

Prior to shaping, blocks to be jointed need to be sorted and defects cut out to specific quality criteria, as end sections must be perfectly square and free of defects.

Finger-joint profiles are manufactured with cutting tools (a revolving head made up of a series of stacked knives, shaped saw blades or a head holding replaceable bits). Two major causes of poorly fitting finger-joints are improper finger length and improper cutter bevel. Critical cutting parameters are the cutting speed, the feed rate and the depth of cut.

Incremental Technological Innovation

- *Develop and implement a two-stage finger-jointing technique, whereby lumber pieces are assembled in a preliminary jointing operation that develops enough strength for handling and reprocessing.*
- *Develop and implement a computer-assisted vision system to detect and reject pieces with defective fingers, and to check adhesive application and spread, in order to eliminate weak joints and facilitate maintenance and set-up.*

Breakthrough Technological Innovation

- *Develop and implement jointing technique combining finger-joints and another feature (e.g., dowels, synthetic fibres, new adhesives) to reduce finger length in structural joints.*

7.3.2.4 Adhesive Application and Pressing

Existing Technology

With soft roller applicators, the adhesive is continuously applied to grooved rollers. The adhesive-impregnated rollers transfer the adhesive to the material to be coated. The quantity of adhesive is regulated by adjusting the distance and the pressure applied by the roller to the wood.

With spray adhesive applicators, the adhesive is atomised and transferred to the wood. Since the system is not sensitive to the position of the surfaces, it can reach the hidden horizontal planes of irregular pieces. The quantity is regulated by the system pressure and the characteristics of the adhesive.

With comb applicators, a profiled comb extrudes the adhesive to the wood. The spread is regulated by a computer which controls the starting and stopping times for adhesive application to each block.

In the most popular pressing method, the finger-jointed blocks are assembled in a continuous manner then cut to a fixed length, and pressed in the three plane directions into pieces of engineered material.

In large continuous operations, the preferred pressing method relies on the speed differential between two sets of rollers: the front rollers run more slowly than the back rollers, which has the effect of exerting a continuous pressure on the assembled engineered piece of wood.

Until recently, adhesives were water soluble and had to be applied to dry wood fibre. If water were present in the wood fibre cells, it would dilute the adhesive, causing it to wick beyond the joint and weaken the bond. Considerable research effort has gone into developing adhesives capable of gluing wet wood.

Incremental Technological Innovation

- *Develop block positioning and assembly methods sufficiently accurate to eliminate the need for planing after the jointing operation (with attendant dimension problems).*
- *Develop and implement a method to determine and control actual pressure exerted on the joints.*
- *Explore the potential of surface activation as a means of improving adhesive performance (wetting of opposite surface).*

7.3.2.5 Adhesive Curing

Existing Technology

The method commonly used in industry relies on radio-frequency (RF) heating. Its main advantage is that it tends to concentrate energy where there is conductive material, so that a water-containing adhesive constitutes an easy path for RF energy. The heat build-up within the glueline is highly dependent on moisture content and wood density, which means that wood moisture content needs to be sufficiently uniform to avoid power dispersion.

Some western Canadian operations rely on a curing technique developed by the Western Forest Products Laboratory (now Forintek Canada Corp.), which involves drying the fingers to an acceptable moisture content before the resin is applied and cured. Then the two pieces are assembled, pressed, and they achieve 90 per cent adhesive cure within three minutes, which is enough to allow stacking. This method has been used in industry for 20 years, and it is currently being applied to the finger-jointing of green lumber shorts in two British Columbia operations. The resulting joints meet all the requirements of NLGA SPS 1 and SPS 3 standards.

Incremental Technological Innovation

- *Develop new adhesive systems for dry lumber that combine ease of application and reduced energy usage, and meet the requirements of structural standards.*
- *Optimise adhesive systems under development for green lumber, and ensure adequate recognition in structural standards.*
- *Develop and implement closed-loop adhesive curing systems capable of adjusting energy as a function of wood moisture content and other critical factors.*
- *Develop on-line finger-joint evaluation systems to test every joint and eliminate the need for off-line proof-testing.*

7.3.3 Glued-laminated Timber (Glulam)

Existing Technology

Glulam is one of the oldest engineered wood products. It consists of rows of lumber "laminations" assembled into a beam with the assistance of a high-performance exterior-grade adhesive. The laminations are typically kiln-dried 2x3 to 2x12 pieces of lumber, finger-jointed and visually or machine stress-rated. Douglas-fir and southern yellow pine are the most commonly used species in North America, but spruce (white and black) and pine (jack and lodgepole) have been increasingly used in Canada.

Even though glulam has been associated with stadiums and other spectacular applications with clear spans of 100 metres or more, most glulam products are more modest. They are used in residential construction, office buildings, schools, and other institutional, commercial or recreational buildings as substitutes for steel. North American demand for glulam has remained relatively stable at around 700,000 m^3 (300 million fbm, APA – The Engineered Wood Association), and Canadian production amounts to less than five per cent of the North American total. Unless exports pick up again or there is a resurgence of its use in light commercial buildings, glulam production in Canada is expected to remain stable.

Standard glulam dimensions range from 80 to 365 mm (3 to 14 inches) in width, with depths ranging from 114 to 1820 mm (4.5 to 71 inches). Laminating stock (lamstock) is typically 38 mm (1½ inches) thick. Glulam plants typically purchase lamstock conforming to special provisions in NLGA grading rules which specify thickness and moisture content tolerances (7 to 15 per cent); lamstock is stored under controlled climate conditions (15 to 20°C and 55 to 65 per cent relative humidity) for one week before assembly. Appearance defects tolerated in glulam production vary with applications (architectural, industrial or commercial).

In plants specialising in large glulam products, the laminating process is performed at room temperature; the resorcinol-formaldehyde adhesive is cured over a period of about 10 hours.

New products resulting from the combination of wood with fibre-reinforced polymers (FRP) are emerging under the designation of "advanced engineered wood composites" (AEWC). These products offer many advantages, such as increased strength, stiffness and ductility, reduction in member sizes, etc. The addition of FRP to species not previously considered suitable for structural applications also represents an opportunity to enlarge the resource base. Research is under way to analyse the behaviour of wood/FRP combinations, but many questions remain unanswered. The movement of wood subjected to changing humidity conditions, and the effect of such movement on the wood/FRP composite are two such issues. Durability of the system also needs to be clarified.

Innovations identified by the industry relate mostly to reducing costs through greater flexibility in terms of wood species, wood grades, adhesives, lay-up, etc. Other suggestions aim at developing a new generation of glulam products that combine regular wood laminates with other materials, preferably within the framework of innovative systems (e.g., for residential construction).

Incremental Technological Innovation

- *Develop material property information on new species, such as aspen, to allow them to be used in glulam construction.*
- *Adapt glulam technology to the use of commercially available MSR lumber to eliminate the need for re-grading lumber.*
- *Develop glulam lay-ups based on Canadian species for acceptance in the US. Current lay-up formulas favour US species.*
- *Develop new stress rate categories for bending or compression to optimise the use of species such as black spruce.*
- *Develop the use of glulam members connected with metal truss plates.*

Breakthrough Technological Innovation

- *Pursue the development of new generations of glulam products, particularly wood/FRP composites.*
- *Develop new adhesive systems to increase productivity through shorter curing times, and obtain acceptance for such systems.*

7.3.4 Wood I-joists

Of all engineered floor products, I-joists, also known as I-beams, have gained the most significant market share. From 1994 to 1997, the share of total floor area built with wood I-joists grew from 20 to 30 per cent. As a result, North American production of I-joists went from 36 million metres (120 million linear feet) in 1987 to more than 242 million metres (796 million linear feet) in 1999 (*Resource Information Systems Inc.: Wood Products Review*, January 2000), and it is expected to reach 360 million metres (1.2 billion feet) by 2002. According to APA – The Engineered Wood Association, 81 per cent of I-joists produced are used in floor applications; spans are theoretically unlimited, but, due to economic considerations, they tend not to exceed 12 metres (40 feet).

This product is appreciated for its light weight and ease of installation. It is also considered a more stable product (resistance to warping) than solid sawn lumber. Builders using I-joists recognise that the installed cost of I-joist floor construction is lower per square metre than similar construction with solid lumber. Wood I-joists have been increasing their penetration of the North American residential market. The I-joist business is highly competitive, and any innovation regarding the product or its manufacturing process needs to maintain or improve current production rates.

A typical I-joist assembly plant consists of a web preparation line, an I-joist assembly line, a curing section and a packaging section. Turn-key systems range from low production manual systems that operate at speeds under 30 metres (100 feet) per minute to automated high speed systems that operate at speeds of up to 120 metres (400 feet) per minute.

7.3.4.1 I-joist Design and Materials

Existing Technology

Wood I-joists are made of a panel-type web glued to a top and a bottom flange with an exterior-grade adhesive. Flanges can be LVL, but they are frequently made of visually-graded or MSR kiln-dried softwood lumber (typically 2x3 or 2x4), either solid or finger-jointed. Large US I-joist producers and distributors have shown much interest in I-joists with solid wood flanges made from dense Canadian spruce. Black spruce from the northern boreal forest is known to have the highest strength of any softwood in North America. Black spruce flanges are an economical alternative to laminated veneer lumber flanges, and they represent a major potential market for SPF lumber from the boreal forest.

I-joist design has been relatively stable, with most innovation taking place around the critical joint between the web and the flange. Double web joists have also been designed; acting like a box beam, they are stiffer and more stable than regular single web I joists; they allow the use of 2x4 lumber on edge, and provide longer spans for a given depth. Forintek scientists also developed the Z-beam, a variation on the I-beam concept which maximises product reliability and ease of fabrication. In this product, flanges are made of split 2x4s, and webs take advantage of the high shear strength of OSB.

I-joists made from hardwood flanges (especially the bottom flange, which works in tension) would permit longer spans, but concerns exist as to the practicality of processing hardwoods (grooving, etc.) and possible difficulty with nailing the product on site. More comprehensive technical and economic feasibility studies are still necessary to evaluate the potential of this technology.

Incremental Technological Innovation

- *Investigate the economic and technical feasibility of using alternative wood species, including hardwoods, in I-joist construction.*
- *Investigate innovative flange-to-web connection design to maximise load transfer while reducing cost and improving reliability.*
- *Improve wood I-joist performance through the use of reinforcements such as fibre-reinforced polymers (FRP).*

7.3.4.2 Web Preparation

Existing Technology

Standard packages of web-grade plywood or OSB panels are loaded onto a de-stacker. Individual panels are fed through a multi-rip-saw to rip panels to size. Some manufacturers rip along the length of the panel, producing 2.5 to 3.6 m (8 to 12 foot) web strips, and other manufacturers rip across the panel, producing 1.2 m (4 foot) web strips. The individual webs are then fed through a profiler and profiled along both long edges for the web-to-flange joint. The webs are then fed through another profiler section which profiles the ends of the strips for web-to-web joints. The webs are then stacked and transferred to the I-joist assembly line.

7.3.4.3 Assembly

Existing Technology

Lumber flanges are fed longitudinally on edge into the end of the assembly machine. They pass through a profiling section which cuts a groove on the inside face of the flange for the web-to-flange joint. The adhesive is then applied to the groove.

Webs are transferred in stacks from the web preparation line to the assembly machine. They are de-stacked and a resorcinol adhesive is applied to the groove at one end of each web. The webs are then top-loaded into a magazine, which is located near the centre of the assembly machine.

To form the joist, flanges proceed through the assembly machine on edge. Webs are bottom-released from the magazine as required. Side pressure rolls press the flanges and webs together to form the joist, and top and bottom pressure rolls force the web-to-web joint together.

The web-to-web joint creates a continuous web, but the length of each joist is limited by the length of the flanges. A scanner locates the end of each flange and a flying cut-off saw cuts the joist to length.

7.3.4.4 Adhesive Curing

Existing Technology

One important consideration for I-joist producers in selecting an adhesive is the time-temperature relationship for curing. Some formulations need elevated temperatures to cause the chemical reaction, while other formulations will cure over an extended period of time at room temperature. High speed continuous processes use a heat-sensitive adhesive and cure the joists in an oven. Retention times in the oven vary depending on temperature, but, as an example, at 65°C it takes 11 to 20 minutes. The adhesive is approximately 90 per cent cured at this point and is considered to be cured enough for the joist to be handled and stored outside, even at temperatures below freezing. Final curing takes place over several days.

Smaller manufacturers may choose to store their production inside the plant until the adhesive is cured. With this approach, it is necessary to store the joists at room temperature for 24 to 48 hours.

After curing, the joists are inspected, trimmed to length, and stacked into bundles. The bundles are then wrapped, strapped and transferred to outside storage.

Incremental Technological Innovation

- *Develop fast-curing structural adhesive systems to reduce holding time and obtain approval for such systems.*

7.3.5 Metal-plate Connected Roof Trusses

Taking over from early trusses that were assembled with nailed plywood gussets, metal plate connectors were invented around 1950. Pre-engineered, metal-plate-connected roof trusses, made from SPF species, rapidly penetrated the Canadian residential market in the 1960s, reaching near saturation by the early 1980s. They offer long, clear spans and allow complex roof designs. Wide use of MSR lumber allows designers to reduce safety factors in their calculations (and therefore costs) without increasing the risk of failure.

Current sales of trusses total about $450 million annually, and the industry involves some 300 fabricators who also distribute or manufacture parallel-chord trusses. With the introduction of micro-computers ten years ago, fabricators have been able to design their own trusses on the basis of programs developed by metal-plate suppliers located in the US.

The Wood Truss Council of America estimates that metal-plated wood trusses are now used in over 75 per cent of all new residential roofs in US single family construction. This proportion is probably closer to 90 per cent in Canada. Wood trusses also dominate the agricultural building market, with some competition from steel trusses. Commercial buildings, where steel is the norm, represent the greatest potential for wood trusses. Given the size of trusses, transportation costs constitute a major obstacle to distant sales, but, over the past few years, Canadian producers have been increasing sales in neighbouring US states.

Innovation in this sector relates mostly to the use of computer tools to design increasingly complex roof structures at minimum cost, to diversify production into floor and wall components, and to optimise production costs.

Existing Technology

Roof trusses are always designed and fabricated for a specific job. Design technicians read plans and use a computer program to design trusses, prepare quotations and produce the cutting list for lumber (predominantly 2x3 and 2x4). The lumber is cut to the required lengths in multiple head saws. Truss assembly takes place on large tables equipped with jigs, and the connector plates are pressed into the wood by roller presses. In larger operations, the cut-up saws and assembly jigs are computer-controlled.

Quality control is done internally, except in British Columbia and Alberta, where third-party quality control programs have been instituted.

Incremental Technological Innovation

- *Define conditions for the use of finger-jointed lumber in trusses.*
- *Apply scanning/grading techniques to the optimisation of lumber for use in truss fabrication.*
- *Develop more efficient design tools to help truss fabricators diversify production.*
- *Investigate design concepts to reduce product bulk and facilitate long-distance shipping.*

Breakthrough Technological Innovation

- *Develop high performance trusses by combining existing technology with new designs or materials such as fibre-reinforced plastics.*

7.3.6 Parallel-chord Trusses

Parallel-chord trusses have also been used for a number of years. They are based on the same engineering principles as I-joists, except that the web is made of a triangulated system of steel or wood components. Typical flange material is kiln-dried, visually-graded or MSR lumber (mostly 2x3 and 2x4). Truss depths typically range from 230 mm (9 inches) to 600 mm (24 inches), although deeper trusses are manufactured for special applications.

When wood is used as the web material (metal-plate-connected wood web floor trusses), it is normally assembled to the flanges through metal plates of the same type as used in roof trusses. Trusses are also manufactured with light-gauge metal webs (metal web floor trusses). Parallel chord trusses have also seen more design innovation than any other form of engineered wood product, and manufacturers have created a number of variations to this design. In one of these, which was developed by a Quebec company and has been on the market since 1990, solid wood web components are assembled to the flanges through a glued finger-jointing arrangement (wood web floor joist with glued joints). Another product uses strips of glued panels as a web; in fact, this product can be manufactured as an open-web truss or as an I-joist (with a full web).

In Canada, parallel-chord trusses are manufactured by about 50 companies with combined sales of $35 million. Plant capacity averages 150,000 metres (500,000 lineal feet) per year, with one plant exceeding 3 million metres (10 million feet). By comparison, some highly-automated US plants produce 15 to 30 million metres (50 to 100 million feet). Parallel-chord trusses essentially compete with wood I-joists for the same market applications. I-joists tend to be more popular in Western Canada, while trusses still hold 50 per cent of the market in Quebec and the Maritimes. I-joists enjoy a price advantage because they are manufactured in larger, more automated facilities. Parallel-chord trusses tend to be custom manufactured in smaller plants, for a local market. They are produced by companies that also produce roof trusses and sometimes wall panels or other plated systems.

Incremental and breakthrough technologies applicable to roof trusses are also applicable to parallel-chord trusses.

7.3.7 Other Engineered Wood Products

7.3.7.1 Edge- and Face-glued Dimension Lumber

In the same vein of adding value to small diameter lumber, a variety of products have recently been developed which are produced by edge- or face-gluing smaller pieces into larger sections. Such products are being put on the market to replace 2x10, 2x12 or larger sections of solid lumber. Species commonly used are spruce and pine in Eastern Canada, Douglas-fir and larch in the west.

Manufacturing techniques are similar to those used in appearance products, except that adhesives must satisfy the requirements of appropriate standards for structural products. Lumber pieces making up the product may be laid up in such a way as to maximise performance, i.e., with higher grades on the outside. Because of the way the products are assembled, the components must be fabricated to close tolerances. As with glulam and most glued products, moisture content also needs to be within a relatively narrow range (7 to 15 per cent) to ensure end-product stability.

7.3.7.2 Engineered Studs

Another upcoming trend in engineered wood products is the development of engineered wood studs. This is also motivated by a desire to process small wood, add value to the products and provide materials that are easier to install. The development of engineered wood studs makes it possible to produce a 30 mm (6 inch) wall thickness (for insulation purposes) with less wood while maintaining the required design values.

A variety of these products have recently been introduced on the market. Among them are profiled finger-jointed studs with openings; these studs are profiled for ease of installation and pre-manufactured openings allow contractors to run cables and plumbing more rapidly during construction. They can also be notched and pre-drilled.

7.4 Manufacturing Operations Common to Most Engineered Wood Products

By definition, engineered wood products are designed to achieve high product performance through the organisation of selected wood components in such a way that parts with the highest tensile strength, for example, will be stressed in tension, while lower grade parts may be used near the neutral axis. This is made possible by pre-sorting and pre-grading lumber pieces in order to optimise the lay-up. Consequently, optimisation of the end-product requires that each step of the way be optimised.

7.4.1 Wood Resource – Preliminary Sorting

Existing Technology

As engineered wood products can rarely be manufactured from all species included in common commercial groups such as SPF, the process begins with species sorting. As discussed in Section 4, Softwood Lumber, very little equipment is currently available for species recognition, and research is therefore needed. Given that drying tolerances are relatively strict, it is also advisable to sort the lumber into groups of equivalent dryability characteristics, so as to facilitate the drying process and foster production of moisture content uniformity (see Section 4.12).

Manufacturers of engineered wood products have an interest in diversifying the wood supply, and they have been looking at alternative species such as larch, aspen, or plantation poplars for possible use in their products. In each case, technical information is needed on the species considered, and older information needs to be revisited as the resource has frequently changed; in addition, some characteristics considered critical today, like gluability, may not have been considered in older research.

Incremental Technological Innovation

- *Develop and publish information on the mechanical properties and machining characteristics of all Canadian species showing a degree of commercial potential, with a view to providing manufacturers of value-added products, including engineered wood products, with the technical information they need.*

Breakthrough Technological Innovation

- *Develop and implement new or improved technology to recognise a wide variety of wood species in green or dry lumber form and to segregate them.*
- *Develop and apply dryability criteria for sorting lumber prior to drying.*

7.4.2 Drying

Existing Technology

Products to be remanufactured typically have specific moisture content requirements. If they are to be ripped or otherwise resawn, moisture content gradients may cause warp or other forms of unacceptable distortion. If they are to be glued, adhesives performance is normally tied to a fairly narrow range of moisture content (e.g., 7 to 15 per cent), and that range is significantly lower than standard requirements for construction lumber. The consequences of high moisture may also be more serious than in construction lumber, as would be the case with a defective finger-joint in tension in an I-joist. In addition, wood pieces to be jointed with an adhesive should be at about the same moisture level to avoid distortion in the finished piece; this is particularly critical with finger-jointed material. For all these reasons, the recommendations regarding softwood lumber sorting and drying made in Sections 4.12 (Sorting on the Green Chain) and 4.14 (Drying) apply equally here.

When the material used for engineered wood products has been dried in regular sawmill facilities, moisture content average and variations are not the only factors to be considered. Moisture gradient may also cause problems, and should be covered by strict specifications. Mills can introduce an equalisation phase in their drying schedule, but they will only do so if they have to. Questions have even been asked regarding the suitability of high-temperature drying, as it may affect the mechanical performance of high-stress material such as that used in I-joist flanges.

Plants that dry their own material are obviously in the best position to obtain the specifications adapted to their product and process, provided they are aware of the importance of high-quality drying. Whether they dry their own stock or consider some form of "finish drying" operation to improve on what they receive from the mill, they probably should consider different types of drying processes, such as dehumidification kilns, or even radio-frequency (RFV) or superheated steam/ vacuum (SS/V).

RFV and SS/V drying techniques appear to offer solutions to brown discoloration problems in species such as hard maple, western hemlock or eastern white pine. They may also develop into cost-effective methods to dry wetwood-prone species, such as western hemlock, subalpine and balsam fir, or aspen and poplars, to the specifications required by engineered wood product manufacturers.

A number of manufacturers are still looking for ways to handle and dry short lengths (down to 150 mm [6 inches] or even less).

Incremental Technological Innovation

- *Provide engineered wood products' manufacturers with correlations between the various types of moisture meters so that operators may have access to accurate and reliable measurements.*
- *Develop drying specifications for engineered wood products' manufacturers and their suppliers.*
- *Investigate the effect of high temperature drying on the mechanical properties of structural softwood lumber, and provide recommendations.*
- *Develop and demonstrate alternative drying techniques in engineered wood products' facilities.*
- *Develop and implement a technique for handling and drying short lumber blocks.*
- *Develop tools to help kiln operators meet drying specifications.*

7.4.3 Wood Grading and Preparation

Existing Technology

As indicated earlier, engineered wood products usually involve the arrangement of components in such a way that they are used to the maximum of their potential on the basis of engineering principles. Specific information on the mechanical properties of each piece is therefore essential. Information on its chemical and physical properties may be needed for gluing or other manufacturing processes, as well as information on its geometry (precise dimensions, skip, wane, etc.) or the natural defects it contains (knots, decay, shake, checks, etc.). In some cases the information will serve to grade the piece, and it will be used as is. In other cases, the piece will be "defected", i.e., the defect will be cut off and the sections of "good" wood reassembled, generally by finger-jointing.

The grading operation clearly requires precise, optimised specifications for the parts needed in a particular process. Noted above, it also requires accurate measurement of moisture content.

Various types of mechanical grading systems are available to evaluate stiffness (e.g., Metrigard E computer, MSR machines); they are reliable, but they have limitations as to the lengths of lumber they can handle. In addition, they only measure stiffness, and all other properties are derived through algorithms, so they cannot be optimised. Vibration techniques currently under development could provide measurement of true bending and shear stiffness, as well as axial stiffness. Other methods need to be investigated, including methods to grade short pieces like trim blocks, so as to optimise the make-up of engineered lumber.

Equipment is available to accurately measure lumber dimensions and geometry-related defects such as wane, skip and torn fibre (see Section 4.16 Grading and Trimming), but it has not yet been applied to the manufacture of engineered wood products. The detection of decay and other "natural" defects, still needs to be done visually, and consistency can be a problem when line speed is high and different products have different specifications. Automatic scanning is currently being used to detect knots and major defects in the "defecting" operation of finger-jointing plants.

In some wood engineering processes (e.g., glulam, face- and edge-glued lumber), parts must have very precise dimensions, or the dimensions must be known for properties to be accurately evaluated

(MSR). In other processes, like finger-jointing, parts must have exactly square ends before the fingers are shaped, and finger geometry also needs to be accurate. In both cases, failure to adhere to the specifications may cause a faulty joint and eventual failure if it is not caught by the quality control process. Quality and process control issues are discussed in Section 7.4.6.

Incremental Technological Innovation

- *Further develop the "free-free beam" vibration technique for on-line evaluation of true bending and shear stiffness.*
- *Develop the longitudinal vibration technique for on-line evaluation of axial stiffness.*
- *Develop other non-destructive techniques to evaluate critical lumber mechanical properties for engineered wood products.*
- *Develop and implement practical stress-rating method for trim blocks and other short lumber pieces to allow for sorting prior to assembly into engineered products.*
- *Further develop scanning techniques available to the lumber manufacturing industry, and adapt them to engineered wood products' manufacturing processes.*

7.4.4 Handling Systems

Existing Technology

In some cases, engineered wood products' manufacturers need to handle large quantities of relatively small pieces, or lots of mixed lengths. This is frequently done by hand, and operators may have difficulty keeping up with the manufacturing equipment, causing a productivity deficit as well as operator fatigue.

Incremental Technological Innovation

- *Develop and implement handling systems for small parts. These may be adapted from other industry sectors (e.g., furniture, automobile, consumer goods).*

7.4.5 Gluing and Adhesives

Existing Technology

Many engineered wood products rely on glued joints for performance. In Canada, the standards that govern gluing specifications for structural wood members allow only two types of adhesives: resorcinol-formaldehyde (RF) and phenol-formaldehyde (PF), or combinations of the two (PRF). Both adhesives are waterproof, with a long history of satisfactory performance. RF cures at room temperature over a period of a few hours, and it is used mostly in glulam production. PF cures in a matter of minutes, but it needs to be heated in an oven, a hot press or with the help of other forms of energy, such as radio-frequency. Although these adhesives have to meet standard specifications, they come in many specifications, and they are only tested on a known medium (or reference material). Given the many variations in wood chemistry and structure, optimisation of the adhesive for a given species is likely to yield improvements in curing time, ease of application, bond strength, or long-term performance. One of the variables to be considered is moisture tolerance; in some cases an adhesive more tolerant of moisture variations may provide a cost-effective alternative to very tight moisture specifications. It should also be remembered that, in some composites, like I-joists, solid wood is glued to OSB or plywood. In other situations, it may be glued to metal or plastic.

The only other adhesive permitted by Canadian standards in structural applications is polyvinyl acetate (PVA), and this is restricted to studs for vertical use. While there are historical reasons for industry's caution regarding structural adhesives, competitors in the US and elsewhere have access to a broader selection of adhesives (e.g., melamine, melamine-urea, etc.). In addition, laboratories have been formulating new types of adhesives, such as polyurethanes, which show promise. Work is currently in progress to develop testing procedures and criteria that should expand the industry's choices of innovative adhesives systems, including two-component adhesives (e.g., soya protein and PRF resin, or a PRF and ammonia-based formulation developed for gluing green finger-joints). The possibilities are endless, but development needs to be undertaken against a set of criteria.

Adhesives may be applied through curtain coaters, spray systems or transfer rollers. Whatever the mode of application, it is difficult to measure how much adhesive has been applied.

With borate-treated wood being increasingly accepted as a defence against termites, it may become a desirable material for engineered wood product manufacturers courting southern US, Japanese or other markets where insects are a problem. Accordingly, adhesives will be needed to glue such treated wood, or even wood treated with conventional chemicals. As with other adhesives, long-term performance will need to be assessed carefully.

Ideal resin systems would cure rapidly at room temperature. Practically, however, some form of energy is likely to be needed, and research should continue into alternatives to current bonding systems.

Incremental Technological Innovation

- *Optimise resorcinol and phenol-based adhesives for individual wood species, moisture tolerance, etc.*
- *Develop and implement a system to measure and control adhesive dosage in finger-jointing and other engineered wood product manufacturing processes.*
- *Develop test methods and criteria for the evaluation of innovative structural adhesive systems.*
- *Formulate two-step adhesive systems capable of developing enough immediate strength to allow handling, with complete curing taking place over time.*
- *Develop fast-curing adhesive systems with extended pot-life characteristics.*
- *Develop a protocol for assessing the long-term performance of structural adhesives and their interaction with preservative or fire retardant treatments.*
- *Develop and implement new adhesive-curing technology based on alternative forms of energy (e.g., microwave, ultra-violet, infra-red).*

7.4.6 Quality and Process Control

As explained earlier in this section, engineered wood products by their very nature require process and quality control procedures at every step in the manufacturing chain, at least if the manufacturer has made it its goal to optimise product performance against product input. Process control may need to cover a variety of factors such as species, moisture content (average and variations), dimensions, geometry and natural defects, stiffness and other mechanical properties, surface characteristics, temperature of the wood, grain orientation, adhesive characteristics, adhesive application rate, piece positioning, pressing conditions (temperature, pressure and time). Once the products have been glued, information is needed on bond and overall product quality. Metal-plated products need to be subjected to similar quality control procedures.

To a large extent, quality control operations are currently performed manually, with operators taking samples off the line at more or less regular intervals to check product quality. Sampling is not statistically significant, and results are usually not known until several hours later, so that flaws in the process can be very costly. Solutions to this problem, and to improved reliability, include an array of non-destructive techniques and computer-based vision systems. Many of these systems are still under development, and they may prove costly for smaller manufacturers.

With ISO 9000 and 14000 registration becoming a significant business, plants manufacturing engineered wood products may have to consider registration. This involves a significant investment, but experience has shown that, when the exercise is treated as an opportunity to streamline processes, the investment can be recouped quite rapidly through reduced production costs and improved product quality or service credibility.

See Sections 4.18 and 5.11 on Overall Quality and Process Control for more details.

Incremental Technological Improvement

- *Develop on-line scanning and image analysis equipment or other technology to control geometry and natural characteristics prior to assembly.*
- *Develop and implement an on-line non-destructive quality control system to ensure total quality and eliminate the need for manual tests.*
- *Develop and implement testing methods to evaluate creep and duration-of-load characteristics of engineered wood products.*
- *Develop quality control protocols and tools that could be used widely by industry to increase product reliability and credibility.*

Breakthrough Technological Improvement

- *Develop and implement a centrally-integrated process control system incorporating feedback from the various operations, as well as economic and market input, to automate machine set-up, optimise production in real time, and provide tools and data for simulations and process optimisation decisions.*
- *Develop expert systems and decision aids capable of integrating information collected by the quality control equipment in order to alert operators to problems, and to guide their machine set-up and production decisions.*

7.4.7 Product Acceptance and Market Access

Existing Technology

Many engineered wood products, particularly those introduced in recent years are not yet included in North American building codes, and market acceptance will normally require evaluation and on-going certification by an accepted independent agency. With performance-based codes being introduced in Canada and elsewhere, engineered products will be in a better position to gain market access. Manufacturers, however, will still be faced with the responsibility of demonstrating performance, and experience has shown that such demonstration can be extremely expensive, especially when the product does not fall into a recognised family of products. The situation becomes even more complicated for acceptance in foreign countries.

Incremental Technological Innovation

- *Develop methods to demonstrate the performance of existing and new engineered wood products under performance- or objectives-based codes and standards in Canada, the US and other export countries.*
- *Develop and obtain approval for links between on-line process control and third-party certification.*

7.4.8 Design

Existing Technology

Engineered wood products have been designed by a variety of people, some with an engineering background, and others without; an engineering background does not guarantee innovation, but it sometimes helps to avoid pitfalls by taking design into consideration. Even when engineered wood products replicate traditional products like 2x10 or 2x12 lumber, they have to meet performance specifications (see above). Handling and installation instructions need to be provided as well as design values for engineers; and acceptable ranges of applications may need to be defined. Of course, this is all part of the evaluation and acceptance process, but it really needs to be handled up front, when the concept for the product is still being defined.

In most situations, the performance of building products in-service cannot be evaluated independently from the system in which they will be used. This is definitely the case for fire resistance, durability, serviceability, acoustic performance, and even cost-effectiveness, so that component design should be fully integrated with building systems design. Performance-based codes are creating a unique opportunity to introduce innovative engineered products through the design of innovative building solutions.

To understand the needs of designers and specifiers, to meet the requirements of certification agencies, and to implement modern process and quality control techniques, manufacturers of engineered wood products require a variety of tools and expert systems. This is particularly the case in the small- and medium-size operations typical of this industry sector, where structural engineering, wood science, computer science and industrial engineering skills could be in short supply.

Incremental Technological Innovation

- *Develop and package the technology and computer-based tools required to guide manufacturers of engineered wood products through the design of their product or system.*

Breakthrough Technological Innovation

- *Develop a new research and development initiative aimed at creating the necessary conditions for market-driven building systems and engineered building material design to take into account all systems factors affecting building performance, including environmental impact, fire safety, durability, serviceability, ease of construction, building cost, maintenance cost, etc.*

CONCLUSIONS FOR ENGINEERED WOOD PRODUCTS

Engineered wood products are a very active sector of the Canadian wood products industry. Business has been expanding at a very brisk space over the past decade, creating jobs and generating export revenues. Even though this situation has partly been a consequence of the quota affecting lumber shipments to the US, there is every reason to believe that growth will continue. For value-added products such as engineered wood products, economic success requires continuous adaptation to market requirements through innovative design and aggressive marketing, as well as technological innovation to reduce production costs while expanding raw material options and product specifications. This will require dynamic market intelligence as well as technology for improved process and quality control.

Continuous development of the engineered wood products industry will require access to skills (technical, economic, marketing) not frequently available to small- and medium-size wood product manufacturers, and ways must be devised to make such skills accessible.

Engineered structural products should be designed and optimised in the context of complete building systems. To achieve this, a recommendation is made for a major R&D initiative to be developed in order to create the conditions for a comprehensive market-driven approach to systems and product design.

8 Appearance Products – Existing and Future Technology

8.1 Introduction and Overview

The term "appearance product" can be used to describe a number of finished products made from hardwood or softwood lumber. Typical products include treated wood for exterior use, sidings, decorative boards, mouldings, window and door components, flooring, and furniture components. This wide array of products requires different processing machinery, equipment and plant layouts.

Over the past 20 years, the secondary wood processing industry has undergone major changes. Processing speeds have increased; machinery set-up time has decreased; production batch sizes are smaller; product specifications have multiplied; and quality control procedures such as ISO 9000 are being introduced.

Manufacturing appearance products generally requires high-quality wood, which is expensive and not as abundant as lower-grade wood. Vision systems to scan input lumber for defects are now used in conjunction with optimised cross-cut and rip-saw operations to improve lumber yield. Tooling improvements are being applied, such as super-thin saw blades with kerfs as narrow as one millimetre (0.039 inch).

A growing number of specialised lumber breakdown operations producing cut stock are appearing, as they can produce components at a lower cost than individual plants by using the latest optimising technology and processing techniques.

Computerised numerically controlled (CNC) machines are standard in modern secondary wood processing plants. Programming these machines has become more user-friendly and less time consuming. Most of the programming software works in a graphical or windows environment. Computer-assisted design (CAD) drawings of parts can be downloaded directly to individual machine centres for processing. Robots are being used mainly in wood finishing tasks but also for loading and unloading flat panel stock into machines.

The current trend to bring work pieces to a machining centre where multiple tasks are performed may be replaced in the future by systems where work pieces travel by different CNC machines on a vacuum transport band—each of these machines moving to the work piece and performing one or more operations. Such systems are already used in other industries (e.g., automobile industry), but their application to wood processing requires a lot of work on standardisation of interfaces and programming.

In the finishing sector, there is a clear move to high solid ultraviolet (UV) hardening coatings for flat line finished products as these coatings have low volatile organic compound (VOC) emissions and can be dried almost instantly. For non-flat products, such as casegoods and chairs, the move is to using spray systems with higher coating transfer efficiency and coatings that are water-based as opposed to solvent-based.

With the introduction of sophisticated equipment on all production levels, machine operators increasingly become machine controllers. Continuous training of the personnel is the key for proper and efficient use of the new technology.

8.2 Driving Forces

Given that appearance products are market oriented, the growth of the industry will be affected by its ability to access ***dynamic market information world-wide***, and to retain sufficient ***manufacturing flexibility*** to respond to fast-changing market demand.

Traditional high-value hardwoods such as ***hard maple, yellow birch and oak are increasingly in short supply*** in Canada. Although some opportunities remain for ***optimising log allocation*** of these species to the most advantageous use, most of the growth potential in hardwood processing lies in the use of ***alternative species***. White birch is certainly the one species with the most potential, being widely distributed from Newfoundland to British Columbia and available in large volumes on a sustainable basis. Significant potential also lies, regionally, in increased use of species such as red alder in BC, aspen in Alberta and soft maple in Ontario, Quebec and the Atlantic provinces.

Hardwood sawmilling generates various grades of lumber. Typically, the highest grade lumber goes to the furniture industry, medium grades to the flooring industry and the lowest to packaging and pallets. A key factor in the development of opportunities for growth in appearance products is the ability to find markets for the various grades produced, including low grades. For example, if the pallet market is not as robust as the furniture market, a surplus of low grade lumber will be generated, and a number of producers may experience difficulties. This suggests that another driving force for the sector is its ability to ***develop alternative products from lower grades*** of hardwood lumber, either through technology or through marketing and design.

Clear pine, Douglas-fir and western hemlock are typically used for millwork applications, including doors and windows. In recent years, ponderosa pine has lost much of this market to eastern white pine, southern yellow pines and, to a lesser degree, lodgepole pine. A recent development has been ***competition from imported plantation pines*** from the southern hemisphere. One option to compete with these plantation pines is to use available alternatives such as aspen and white birch. In the moulding industry, aspen is already making significant inroads and much interest is being given to white birch. Competition is not limited to other imported wood species; actually most of it comes from ***MDF mouldings***, which have made a major breakthrough in the market in the past few years, and, to a lesser extent, from ***plastics and wood-plastics.***

In exterior applications, ***durability*** will continue to be the key to market success, and maintenance-free wood products would give the industry an opportunity to compete with plastics and metals.

Appearance products represent an advantage with respect to ***environmental impact*** in the sense that they allow most of the manufacturing to be performed at, or close to, the source, thereby eliminating disposal problems for the client. It is also easier to use by-products at source than it is further down the line; this is one of the reasons why increasing numbers of furniture manufacturers, for example, purchase semi-finished components rather than manufacturing them as they used to. The practice of ***outsourcing*** is clearly affecting this industry sector, as is the growth of large distributors like Home Depot or Loew's. ***E-commerce*** is expected to further encourage this trend.

In this context, one driving force for the value-added sector will be ***scanning and data processing technology*** to optimise appearance lumber recovery. Scanning capabilities enabling the detection of all types of defects and colour variation will be crucial, as will technologies allowing the development of alternative species in traditional and new applications. Progress in the industry will also be dependant on its ***ability to harness computing power*** for process and quality control, in order to improve material recovery while improving design characteristics and reducing costs.

Many of the Canadian companies involved in the manufacture of appearance products are relatively small, and one of their challenges is to access advanced technology within the constraints of their ***limited financial resources***. In a parallel fashion, adoption of new technology to achieve the sector's economic objectives requires a variety of ***skills*** (design, technical, economic, marketing) that may not be all present in a smaller company. Training needs to be provided to management and to operators, and will need to be supplemented by ***expert systems***, ***decision-aid tools*** and ***access to consulting specialists and R&D resources***.

8.3 Manufacturing Operations Common to Most Appearance Products

Operations reviewed in this section are common to many plants involved in manufacturing appearance products, but different plants may use different equipment, depending on product line and plant size. It should also be recognised that the production of appearance products is highly customised, so that descriptions provided below may not be typical of all plants.

8.3.1 Raw Material Selection and Preparation

Existing Technology

Manufacturing appearance products requires high-quality raw materials. Hardwoods can be purchased as green or kiln-dried lumber in random lengths and widths in a variety of grades. Kiln-dried hardwoods tend to be in the six to eight per cent moisture content range. Softwoods, on the other hand, are more readily available in the standard Canadian Lumber Sizes (CLS) lengths and widths as green, air-dried or kiln-dried lumber. Many of the softwood species are marketed in combinations with other species as is the case with spruce-pine–fir (SPF), hem-fir, and Douglas-fir/larch. Separation of species, although frequently practised for internal process reasons, is generally not offered, or, if available, it may cost extra. Softwood species that have a history of being used in furniture, such as eastern and western white pine, can be purchased on a ¼ inch basis (4/4, 5/4, etc.) the same as hardwoods though not in random widths.

Throughout Canada, emphasis is placed on finding alternative wood species for manufacturing appearance products. Technical information is being developed on all Canadian wood species, and second-growth variants of old-growth species (such as hemlock) are being studied in various provinces.

Incremental Technological Innovation

- *Develop and implement more efficient species sorting techniques.*
- *Develop and implement cost-effective technology to rip short blocks.*

8.3.2 Drying

Lumber products to be remanufactured typically have to meet specific requirements in terms of moisture content average and distribution. If they are to be ripped or otherwise resawn, moisture content gradients may cause warp or other forms of unacceptable distortion. If they are to be glued, adhesives performance is normally tied to a fairly narrow range of moisture contents (e.g., 7 to 15 per cent), and that range is significantly lower than standard requirements for commodity products. In addition, gluing normally requires approximately the same moisture levels in the two parts to be glued to avoid distortion in the finished piece; this is particularly critical with finger-jointed material. For these reasons, pre-sorting and adequate kiln control should be used to ensure adequate quality for value-added production.

When the material used for appearance products has been dried in commodity sawmill facilities, moisture content average and variations are not the only factors to be considered. Moisture gradient may also cause problems, and should be covered by strict specifications. Mills can introduce an equalisation phase in their drying schedule, but they will only do so when required.

Plants that dry their own material are in the best position to obtain the specifications best suited to their products and processes. Whether they dry their own stock or consider some form of "finish drying" operation to improve on what they receive from the mill, they could consider re-drying in a conventional kiln or different types of drying processes, such as dehumidification, radio-frequency vacuum (RFV) or superheated steam/vacuum (SS/V).

For detailed information on drying procedures, see Sections 4.14, Drying Softwoods, 5.8, Drying Hardwoods, and 7.4.2, Drying Wood for Engineered Products.

Incremental Technological Innovation

- *Provide reliable calibration procedures or correlations between in-line moisture meters, hand-held resistance meters and hand-held DC-resistance meters so that all moisture content measurements in the mill are comparable and usable in common databases.*
- *Develop drying specifications for appearance wood products.*
- *Develop technical and economic guidelines for the use of alternative drying techniques for appearance wood products.*
- *Develop and implement a technique for handling and drying short lumber blocks.*

8.3.3 Rough Planing

Existing Technology

When kiln-dried hardwood lumber enters the secondary wood processing plant, its thickness may vary by 1.5 to 3 mm (1/16 to 1/8 of an inch). Rough planing is performed on both wide faces to bring the lumber to a uniform thickness. This also cleans up the surface, permitting visual evaluation of surface defects for the following chop saw/rip-saw operations. Either a knife planer or an abrasive planer is used to equalise lumber thickness. Knife planers can have either staggered or directly opposite top and bottom heads. Helical cutterheads are being used more and more frequently as a means of reducing noise; they also provide shear cutting action that requires less horsepower. Abrasive planers with two opposing heads use coarse abrasives to remove wood material; they require considerably more power than knife planers. Both abrasive double planers and double knife planers have to be designed to remove enough wood on both sides of the boards to produce clean faces.

One of the challenges for this sector is obtaining lumber (softwood and hardwood) with tighter thickness tolerances to eliminate the need for material removal at the planer.

Incremental Technological Innovation

- *Adapt on-line quality control, with automatic moisture sensors and board thickness sensors to determine if boards are within prescribed parameters.*
- *Eliminate rough planing and increase recovery through more precise sawing at the mill.*

8.3.4 Scanning for Grading and Defecting Optimisation

Existing Technology

To manufacture appearance products, defects such as knots, wane, rot, pith, pitch pockets, holes etc. have to be eliminated. Some softwood grades permit the inclusion of knots as long as they are tight or in-grown. The decision whether a defect or character mark is acceptable or not has traditionally been made by experienced, skilled graders. However, the accuracy in detecting defects and speed of grading vary from one grader to another. Scanning systems have been developed to grade accurately and "defect" at high speed.

Scanners reading crayon marks are widely used with the objective of improving the speed of cut-off operations. Some systems are able to distinguish different types of crayon marks identifying different defects. The decision whether a defect is acceptable or not is still made by an operator.

Some systems have achieved a higher degree of automation, and can detect customer-defined defects without intervention of an operator. Four different techniques are available and often combined within those scanning systems, each of them having its own advantages and limitations:

1. Grey scale cameras: high-resolution cameras for detecting small defects clearly identifiable through their colour (e.g., black pin knots). These cameras are less efficient in detecting slight colour differences.
2. Colour cameras: they have less resolution than grey scale cameras but they are more efficient in detecting colour differences.
3. Laser sensors for profile measurement (e.g., detecting wane, knot holes, twist, etc.) and for defect detection (e.g., detecting fibre direction variation around knots and other defects) using the scattering effect.
4. X-ray scans: measuring subsurface density variations to detect internal defects.

Most of the available scanning systems are modular and use a combination of the previously listed methods. Scanning may be performed for one to four sides of the board. The scanners supply data for optimising software controlling cross-cut or rip-saw operations. Despite continuous improvement of the systems, they still lag behind industry requirements.

Incremental Technological Innovation

- *Develop more user-friendly and low maintenance scanner systems to assist human decisions.*
- *Develop or adapt technology to improve scanning rates.*

Breakthrough Technological Innovation

- *Combine a variety of scanning techniques and computer programs to optimise raw material utilisation in an affordable manner.*

8.3.5 Cut-off Sawing

The cut-off or chop saw is designed to perform cross-cutting to eliminate defects or to cut boards to length. Cut-off saws found in secondary wood processing plants may be manually or automatically operated. Manual saws require the sawyer to make decisions as to where to make cuts to eliminate defects and how best to cut the remaining defect-free portion to get optimal results as per a cutting list. Automatic cut-off saws, first introduced in the early 1980s, automate the lumber cut-up operation thereby increasing volume throughput while using fewer people, and obtaining higher lumber yields through optimising programs. Automatic saws can be programmed with a limited number of cutting lists, each with various grades allowed as well as with trim allowances around knots and other defects. They allow the operator to know in real time what has been cut with respect to a cutting list, what percentage has been completed, and what lumber yield has been obtained.

Early scanner models detected crayon marks and encoded the position of the marks for the optimising software to determine the best cutting solution for the board. The saw would then use other software to control board movement and make an accurate cut to remove defects or cut clear sections to length. The station along the take-away conveyor is also programmable, allowing the cut stock piece to be pushed off for stacking. Recent models use scanning technology to determine defect location and type. This information is then fed into the optimising software for processing.

Incremental Technological Improvement

- *Provide more automation in lumber infeed by using vacuum feed or other loading systems.*

Breakthrough Technological Improvement

- *Develop tools to build a cut length and grade database at the cut-off saw, and use it in an optimisation technique integrating product specifications, yield, manufacturing costs, production speed and product value.*

8.3.6 Rip-sawing

Existing Technology

The rip-saw is used to cut boards into strips of equal or different widths as part of the lumber breakout process or as one of the operations carried out on cut stock to bring it closer to its final dimensions. Ripping of lumber along its length may be performed before or after cross-cutting. Ripping prior to cross-cutting yields longer lengths from lower grade lumber, which is often used to make edge-glued panel blanks. The rip-first method is best suited to the production of flooring material (fixed width) but it does require more lumber stock to be processed through the cut-off saw. A cross-cut-first approach is more common in the production of furniture components.

Two different types of rip-saws are commonly used: the straight-line rip-saw and the multiple-rip (multirip) saw, both using circular saw blades on the same shaft. Straight-line rip-saws are used after cross-cutting has been performed to cut straight edges with precise 90° angles between face and edges for edge-glued panel blanks. They may be equipped with a laser guideline permitting the operator to know where the saw cut will be made relative to a defect position on a board.

Multiple rip-saws resemble straight-line rip-saws but they accommodate a number of circular saw blades. They can be used to rip lumber prior to cross-cutting or to re-rip edge-glued blanks into precise widths. Their main application is to rip blanks that may or may not be glued. One of the most important considerations regarding the rip-saw is the width of the saw kerf. To reduce kerf losses, saw blade manufacturers have developed saw blades with very narrow kerf. When relatively narrow rip widths are being produced, the savings from narrow kerf saw blades can be considerable, but these blades require much more maintenance as they have reduced lateral strength. Multiple rip-saws come in various combinations, including fixed-blade variable fence, movable outer blades, and all movable blades.

Incremental Technological Innovation

- *Develop tools and methods to facilitate the accurate grinding of thin sawblades.*
- *Adapt new types of sawblades (e.g., carbide inserts with soft steel backing, ceramic inserts, diamond tooling) from other manufacturing sectors for use in rip-sawing lumber for appearance products.*
- *Automate infeed and outfeed operations.*
- *Develop on-line optimisation methods for all combinations of multiple rip-saws.*

8.3.7 Finger-jointing

Existing Technology

Finger-jointing is used primarily in the construction/renovation sector as finger-jointed lumber (2x4s, etc.) or as paint grade products such as door jambs and window elements. In the past finger-jointing was not considered in processing appearance products; with the increasing value of the raw material, finger-jointed elements were included in the product where they would not be entirely visible, and when the joints are covered with veneer or masked in some way. Today finger-jointing is being used successfully on some appearance products such as table tops with the zigzag pattern plainly visible on the top surface.

Finger-jointing is a method to create long lengths of lumber from short pieces. Sources of short pieces can be mill ends or pieces cut from low-grade lumber. Two types of finger-joint styles are currently in use: horizontal and vertical finger-joints. The former are generally found on North American-manufactured finger-jointing machines, whereas the latter are found on European- and Japanese-manufactured machines. Finger-jointing machines are mostly used in conjunction with softwoods in North America, but they are used for rubberwood laminating in Southeast Asia.

Horizontal finger-joints are created by milling the finger-joint pattern parallel to the wide face of the finger-joint blocks. Vertical finger-joints are created by milling the pattern perpendicular to the wide face of the blocks hence they are visible on the wide face of the resulting finger-jointed lumber. The strength of finger-joints is determined by the finger-joint profile and the type of adhesive used. Longer profiles provide more gluing area, hence a stronger joint, but appearance joints are typically 5 mm (13/64 inch) in length. Polyvinyl acetate (PVA) adhesives are commonly used for appearance applications; alternative adhesives include urea-formaldehyde, melamine and polyurethane.

Horizontal finger-jointing machines are fed by means of a chain which transports the blocks past top and bottom squaring saws and the finger-joint profile cutter. The blocks are then laterally transferred to another chain so that the other end of the block can be squared off and profiled with the same pattern. The second chain also moves the block past a gluing head which can be either a profiled glue roller or a pulse injection head. The former being an open system, it needs to be cleaned up after each shift, whereas the injection system is closed and only the injector head needs cleaning.

The pressing system forcing the glued blocks together may be of the cycle or continuous type. In a cycle-type press, blocks are accumulated, then introduced into a longitudinal clamping system where they are forced together; a cross-cut saw cuts the jointed pieces to length. In a continuous press, the blocks are transferred from a fast moving chain to a slower moving chain; the speed difference between the two chains determines the amount of longitudinal pressure applied to the joints. To accelerate the adhesive curing rate, this type of press is generally equipped with a radio-frequency generator. A cross-cut saw is used to cut the continuous ribbon of finger-jointed lumber into predetermined lengths.

Vertical finger-jointing machines are batch-fed machines in which the blocks are positioned on edge with ends indexed to one end, clamped together and run past a cutter that profiles the blocks. On smaller machines, the clamping section merely rotates so that the other ends can be profiled and run by a glue roller. Larger finger-joint machines have two clamping sections which can work simultaneously for increased production, in which case the second profiling head is followed by a glue roller. The clamping system to form a continuous ribbon of finger-jointed lumber is the same for either type of finger-jointing machine.

Incremental Technological Innovation

- *Develop CNC technology to accurately align various saws and profiling heads so as to obtain tight joints.*
- *Develop grinding techniques to produce more accurate and reproducible fingers.*
- *Apply CNC technology to reduce machine set-up time.*
- *Develop and implement a method to measure and control the pressure applied to the joints.*
- *Develop faster curing adhesives for appearance products, with a method to evaluate bond strength before curing is complete.*

Breakthrough Technological Innovation

- *Develop and implement a computer-assisted vision system to match colour and grain.*
- *Develop and implement a computer-assisted scanning system to measure profile deviations (including squareness and broken fingers) as well as adhesive application.*

8.3.8 Edge- and Face-gluing

Existing Technology

To obtain wider boards, previously ripped lengths (which may be finger-jointed) are edge-glued to form panels of any width desired. Traditionally an operator matches ripped lengths or strips of various widths to form an overall panel width as close as possible to the required dimensions. Optimising systems are now available to compose panel widths within a predetermined range. The strips may also be matched for colour or grain. The strips making up a panel are placed on edge, and pass over an open-roll glue spreader to the clamping system. This process may be of the cycle or continuous type.

Traditionally the cycle-type glue reel is used to clamp panels together. The glue reel operator positions the clamps and lays the strips of one panel between the jaws. Each time the reel moves one section the operator removes the stock from the following one. Before further processing, the panels have to be conditioned for at least 12 hours. Large edge-glued panels may be produced by cycle-type radio-frequency (RF) presses. The wood strips are assembled on an assembly table and are then moved into a horizontal press where the glue lines are cured by radio frequency. While one panel is being pressed, the operator assembles the following panel. The panels can be processed without conditioning.

Continuous-type presses heated with radio-frequency, oil or water produce an endless panel of fixed width which is cut to length by a cross-cut saw. One or more operators assemble the panel on a slow conveyor, and it moves into the pressing conveyor. The length of the press and the feed rate of the conveyor determine the clamping time. After the endless panel has been cut to predetermined lengths, further processing may be performed immediately.

Because radio-frequency energy follows the path of least resistance, successful curing of the adhesive requires uniform moisture contents. Moisture content variations of more than one percentage point from one wood strip to another may cause uneven curing of the glue line, and significantly decrease the product quality. In the newer systems, on exiting the press, the panels are conveyed to double-end tenoners (saws) for final sizing and squaring. A further sanding operation on a wide belt sander may be used to complete the process. Vacuum lifting devices are used to handle the final product and move it to storage. A central computer controls the entire system.

Face-gluing is mainly performed to produce window and door components. As with edge-gluing, RF presses of the continuous- or cycle-type are commonly used. A "three-ply panel" recently developed in Europe consists of two face layers of clear wood strips cross-laminated onto a core of lower quality wood strips; when used as solid wood kitchen cabinet doors, for example, these panels can be routed in the face plies, and they do not require frames. The wood strips are sawn with super-thin saws having a kerf of less than 2 mm (5/64 inch) for increased yield.

Breakthrough Technological Innovation

- *Develop and implement a computer-assisted vision system to automatically sort and match wood strips for colour and grain prior to assembly into edge-glued panels.*

8.3.9 Moulding

Existing Technology

A moulder is one of the key machines used in secondary wood processing. The key value-adding process is to profile stock into specific shapes such as mouldings and wall panelling. The machine is similar to a high-speed planer but the stock must have first been processed through a planer to acquire consistent width and thickness. A moulder can surface all four sides in a single pass. Moulders can also undertake more complicated tasks, such as profiling one or more of the sides as well as surfacing. Profiling involves the use of a tool grinder to shape the knives to pre-selected patterns. The skill level necessary to operate a conventional moulder is one of the highest found in secondary wood processing plants.

A basic moulder is equipped with four cutterheads arranged in the following order: bottom, right, left and top. The first two cutterheads on a moulder not only surface the wood but also provide a precise 90° reference angle for the following two cutterheads, which are generally used for profiling work. By making the initial reference corner, moulders achieve more precise profiling than planers. Being modular, moulders can contain up to eight or more cutterheads. These machines are ideal for cutting complex profile patterns or for cutting deep profiles where each successive head on the top removes progressively more material. Some moulders are equipped with tiltable cutterheads at the back end of the machine to achieve special profiles. Sawing units, generally equipped with super-thin saws, may be mounted on horizontal or vertical shafts for resawing previously squared stock (e.g., wood lamellas for multilayer flooring, or strips for edge-glued panels).

Moulders are usually accompanied by a tool grinder. This allows high speed steel knife stock to be ground to the desired profile pattern in-house, and makes it easier to keep tooling sharp. In situations where high production and a high quality surface finish are demanded, moulders are fitted with a jointing system. This brings all the knives in a cutter block to the same cutting circle, which makes it possible to have a fine finish at high speed.

Moulder knife set-up is a time consuming operation, especially when the knives need to be jointed. Newer models are equipped with CNC controls which reduce set-up time to just a few minutes as long as tooling does not need to be changed. Moulders also come with stackable tool spindles for automated tool changes. These moulders are often found in European window plants where complicated patterns are used in the construction of window elements.

Incremental Technological Innovation

- *Equip moulders with spindles capable of rotating at 9000 rpm, which is 50 per cent faster than standard spindle, to produce higher quality cuts.*
- *Equip moulders with CNC controls allowing the operator to manually set tooling positions with the assistance of a LCD display.*
- *Develop carbide insert tooling for moulders to extend knife life and maintain geometry.*

Breakthrough Technological Innovations

- *Equip moulders with full CNC controls.*

8.3.10 Double-end Tenoning

The double-end tenoner is another key machine used in furniture, window and door plants. It is a high production machine capable of cutting tenons as well as panel stock for furniture components. The tenoner is a feed-through machine with a double row of machine stations, one side of it being fixed and the other movable on a base. Work pieces are transported past the machine stations by feed chains which are driven by the same shaft and have precisely the same feed speed.

The double-end tenoner is modular, and a large number of different tools may be mounted on the machine. The first tools mounted on both sides are generally trim/scoring saw sets which permit panels to be cut with exactly parallel sides. The distance between the two sides of the machine determines the length of the cut stock, and it can be adjusted with great accuracy. For panel processing, the initial sawing units may be followed by shaping, grooving dado-type cutter heads mounted at any desired angle to the work piece. Pneumatically-controlled corner rounding units are also available to perform any work required to complete panel edge machining. The last tools in a double-end tenoner for panel processing are generally profile sanding or chamfering units.

When window or doorframe components are machined, the trim saws are followed by fixed or pneumatic multitool units equipped with antisplintering devices. These units cut grooves, tenons or blind tenons. Drilling units for dowel assembly are also available.

Double-end tenoners can be fitted with CNC controls, tools being mounted on stackable spindles. Setting up double-end tenoners requires a high degree of operator training.

Incremental Technological Innovation

- *Develop tools and methods to facilitate double-end tenoner set-up operations.*

8.3.11 Shaping

Like the moulder, the shaper is used to cut profiles into the edge of stock; however, the shaper cannot profile the top surface. Unlike the moulder, the shaper can be used to profile wide, tapered or curved stock. It can also be used to make blind grooves or tenons down the length of a work piece but not protruding to the work piece ends. Shapers can be fed manually or with a power feeder. Multiple tools may be mounted on the shaper for sawing, cutting grooves or profiling the edges. With a collar set-up, the tool is able to follow a pre-shaped edge of the work-piece or a template attached to the work piece.

Automatic shapers are available wherein one or more panels are held in place by vacuum and the pieces are rotated against a cutter head, a template being used to guide the cutter. A considerable variety of forms or templates need to be made and kept on hand for these machines.

With the development of CNC machining centres, automatic shapers are seeing less usage in woodworking plants. In the future, shapers will only be seen in small woodworking plants.

8.3.12 Routing and CNC Machining Centres

Existing Technology

Traditionally routers have been manually operated, offering the possibilities of surface grooving, mortising and shaping of the interior of any work piece. Forms or templates are required to control the cutting path. With the development of CNC technology, the cutting path, rotational speed, plunge depth and even the tool selection can be guided by computer software. CNC machines use vacuum hold-downs to secure the work-piece to the machine base; with small pieces, however, clamps are sometimes necessary as the vacuum area is insufficient to ensure a good grip. Key advantages of CNC technology are accuracy and repeatability. The programming of CNC machines is time-consuming and requires intensive operator training.

Modern CNC routers are mobile along five axes, the tool movement replicating the movements of the human hand. With this degree of movement, CNC routers can go beyond performing traditional router tasks; they can also be used for carving and shaping in three dimensions. In addition, sawing and boring units can cut work-pieces to size and bore holes in either panel faces or edges. Tools may be changed automatically by tool magazines holding 30 or more different tools. A recent trend is to machine complete parts in a single set-up, reducing handling and transfer time between machining operations.

Programming and set-up facilities have greatly improved over the past years. The numerical control (NC) code, initially edited line-by-line by a skilled operator, may now be generated automatically by drawing software or by scanning images directly into the computer. Systems exist where a camera looks at a part from different angles and creates a complex program. Thus, the machine can be operated by less highly trained people.

The NC program also allows for automatic set-up. Vision systems may detect the precise position of the parts on the table and no referencing of the parts to a zero point is required. Multiple tables are an option that can unload and reload one table while the tools are working on another. Loading may be performed by robots, which have recently been introduced in the wood processing industry.

CNC technology has transformed the wood processing industry. Modernisation of a factory is generally synonymous with replacing older machines with CNC equipment.

Incremental Technological Innovations

- *Integrate CNC software with sales input to generate the materials list; appropriate CNC programs could be generated and sent directly to the machines. This is available for cabinetry (salesperson for kitchen cabinets designs the kitchen with the customer, using dedicated software).*

8.3.13 Boring

Existing Technology

The boring of holes is a very common operation in the woodworking industry. Holes are required for hardware placement, dowel holes, or pilot holes to prevent splitting of the core material. Panel boring has traditionally been done with bit bars in which a multitude of holes can be bored simultaneously in one stroke of the machine. In modern mills, boring machines tend to be replaced by multi-task CNC machines.

8.3.14 Turning

Existing Technology

Turning is one of the oldest wood processing operations known to man. A variety of lathe types are used, depending on wood species, production requirements, product size and quality. The four main types of lathe are the single point lathe, the back knife lathe, the rotary lathe, and the copy lathe. Single point lathes are equipped with a tool carriage moving lengthwise along the work-piece following a template which controls the in/out movement of the knife to shape the turning. This is similar to the manual lathes used with handheld chisels.

Back knife lathes are equipped with one or more knives, each having a specific profile. During the turning process a gouge knife moves lengthwise along the work-piece giving it a rough shape. After the gouge knife has passed, the back knives move downwards at a steep angle to cut the final profile. A set of back knives has to be provided for each profile.

Rotary knife lathes (also called shaping lathes) consist of a complex set of knives set to cut the stock at a sharp angle. In this type of lathe, the knife assembly rotates rapidly whereas the stock rotates slowly. The cutterhead shapes the entire length of the work piece as it moves slowly in towards the stock. This lathe is able to cut non-circular cross-sections through the use of cams. The rotary lathe is the preferred method of turning the less dense softwoods.

Copy lathes are especially designed to produce turnings with irregular cross-sections (e.g., axe-handles). A three-dimensional full-scale model of the turning is rotating and a metal wheel rides on the contours of the model, transferring the cross-sectional profile to an attached cutterhead that machines out the pattern on a blank.

8.3.15 Surface Densification and Heat Treatment

Existing Technology

Wood hardening is a small, but growing industry segment in Canada, mainly focussed on competing with oak in the flooring market. The hardening agents used have mainly been synthetic polymers that are relatively expensive, particularly considering the high loadings required. In New Zealand, cellulose is being used with cross-linking agents and this may prove more economically viable.

Breakthrough Technological Innovation

- *Develop cost-effective wood hardening technology for use in flooring.*

8.3.16 Sanding

Existing Technology

Sanding is performed to improve the surface smoothness of wood for the application of a finish. For panel stock, the most common and efficient machine is the wide belt sander. It can be configured with multiple sanding heads so that sanding may be completed in one pass of the machine. The successive heads use finer-grit abrasives to perform primary, intermediate and finishing sanding.

Modern wide-belt sanders have CNC controls so that feed speed, stock removal rate and sanding pressure can be accurately controlled. Sanding pressure is controlled by CNC technology through electronically controlled segmented platens. Infeed sensors measure the size, shape and thickness of the work pieces and control the segmented platens, which only apply the desired pressure where and when a panel is passing through. Edge-sanding of panel components is usually done manually, as is the sanding of complex solid wood components.

Mouldings are sanded on lineal sanding machines. These machines have a number of small sanding belts oriented at different angles to sand the profiled and flat sections of a moulding. Sanding blocks with the opposite profile to the moulding have to be made for each moulding profile.

8.3.17 Repairs

Existing Technology

The repair of defects in softwoods has been performed in European woodworking plants (millwork, windows and doors, furniture components) and, to some extent, in Japanese woodworking plants for a number of years. Yet this technology has not been adopted in North American woodworking plants. Wood repairs can be performed on knots and longitudinal defects such as checks, pitch and bark pockets. Any loose, encased and unsound knot is bored out with a drill bit slightly larger in diameter than the knot, and a dowel is inserted and glued in its place; this may be a standard dowel or a special dowel made from the stem of a tree branch. Standard dowels are used for paint grade repairs whereas special dowels can be used in appearance situations, where the repair must look like a knot.

The other type of repair is referred to as a boat-shaped patch. Patches come in a number of different profiles varying in width and length; they can be purchased from supply houses in a variety of designs and wood species. It is also possible to make patches in-house, to match the surrounding wood fibre (edge-grain fibre, fibre of different shades, etc.). The machining out of longitudinal defects is done with a machine somewhat like a biscuit joiner in that the tool cutting profile is an exact reverse match for the profile of the patch. Patches are glued into place. Like knot plugs, patches are flushed level with the surrounding wood fibre with a small hand-held router, or they can be sanded flush.

8.3.18 Interior Finishing

Existing Technology

Finishing is the last and most important process in adding value to a wood component for interior use. Finishing lines have gone through considerable changes in the last two decades. Traditional finishing lines consist of a number of spray booths with the work pieces (casegoods, interior doors, shelves, drawers or any other component) being transported between booths by a conveyor system. Coating application is performed by high pressure air spraying. Some high-end furniture plants have as many as twenty steps in their finishing line, and this can be a very labour-intensive operation.

Since the introduction of ready-to-assemble (RTA) furniture, finishing lines have undergone significant changes, including large scale automation. Spraying of stain, sealers and clear topcoat is all done by machine spray systems, all within enclosed cabinets to reduce solvent emissions, and to recycle the overspray.

Flat-line finishing uses multiple techniques to apply coatings: curtain coating, roll coaters and automatic spray applicators in enclosed spray booths. Roller and curtain applicators are commonly used, with the advantage of nearly complete recovery of the coating product. The thickness of each coat is precisely and quickly adjustable, reducing set-up time. With automatic spray applicators, multiple spray nozzles are mounted on horizontal rotating carriages moving across the feed belt of the machine. Sensors detecting position, size, and shape of incoming panels control the opening time of each nozzle. This type of spray coating offers more flexibility than roller or curtain coaters as profiled panels (e.g., kitchen cabinet doors) can be coated. Other types of automated interior finishing systems include vacuum coating for long narrow stock such as mouldings and picture frame stock, and electrostatic coating for intricate items such as chairs, cribs and small objects. Complex three-dimensional forms may be automatically finished by CNC-controlled robots using a variety of spray guns; the technique is beginning to be applied in the wood processing industry to finish complex parts such as chairs and other assembled furniture.

Finish coatings have also changed significantly in the last two decades, mostly in response to government legislation. Coatings with high solvent content are being gradually phased out, or at least used much less. They are being replaced with water-based coatings or coatings with a very high solids content. New spray technology has been developed to apply water-based coatings. High solids coatings are applied with curtain or roll coaters. The more environmentally-friendly water-based coatings have reached approximately the same quality as solvent-based coatings except for the stain coat, where water tends to cause grain raising. Hybrid finishing systems using a solvent-based initial coat followed by water-based topcoats appear to work well.

The possibility of using powder coatings for wood has recently been discussed. Applying this type of coating requires a conducting substrate. Tests have been conducted to increase the electric conduction of dry wood through the application of a water-based layer before powder coating, but the results were not satisfactory. The relatively high temperature needed to melt the powder also affects the wood, producing surface checks or warp.

Curing technology has evolved along with changes in coatings and application technology. A range of curing systems are available to rapidly cure finishes. Curing by radiant heat is still being performed on traditional finishing lines; however, a considerable amount of energy is wasted in heating the air surrounding the product. Ultraviolet curing of polyurethane-based coatings can occur in just one second. This method of curing is used extensively in RTA finishing lines and in flooring plants. Vacuum-coated products can be cured with radiant heat within a long feed-through chamber.

Incremental Technological Innovations

- *Develop more environmentally-friendly high-performance coatings.*

Breakthrough Technological Innovations

- *Develop a technique for the application of powder coatings to wood products. Develop 100 per cent solid coatings to eliminate solvents.*

8.3.19 Exterior Finishing

Processes and products used for finishing wood for exterior applications (siding, cladding, windows, etc.) have not changed as much as their counterparts in interior finishing. Wood products for exterior use are often preservative-treated, with no further finishing. When coatings are applied, spray or curtain applicators are used in most cases, or the components are dipped in the finishing product. Exterior finish coating development is mainly driven by durability; the coatings have to seal out water and resist climatic changes without checking. Oil- or water-based stains and paints are used for this purpose. These coatings are cured by radiant heat.

Wood preservation technology is covered in Section 9.

Exterior applications represent a very sizeable potential market for wood products, but it has long been recognised that success in this market would require "maintenance-free" products, this being the main advantage claimed by plastics and other competing products. Although some commercial cladding products have proved highly durable, they require heavy stains to prevent UV degradation of the underlying wood structure. Existing technology does not permit the production of durable products with a natural wood appearance.

Incremental Technological Innovations

- *Develop more environmentally-friendly high-performance coatings for exterior use.*
- *Develop UV-curable coatings for exterior use.*

Breakthrough Technological Innovations

- *Develop clear finishing systems for exterior wood products through chemical processes to render wood surfaces impervious to UV and moisture degradation, and long-lasting UV-resistant transparent finishes*

8.3.20 Handling

Existing Technology

Manufacturers of appearance wood products need to handle large quantities of relatively small pieces, or lots of mixed lengths. This is frequently done by hand, and operators may have difficulty keeping up with the manufacturing equipment, causing a productivity deficit as well as operator fatigue.

Breakthrough Technological Innovation

- *Develop and implement mechanical systems for automated infeed, outfeed and stacking of variable length parts, including very short pieces (down to 125 mm [4.9 inches]).*

8.3.21 Quality and Process Control

Existing Technology

To a large extent, quality control operations are currently performed manually, with operators taking samples off the line at more or less regular intervals to check product quality. Sampling is not statistically significant, and results are frequently not known for several hours, so that flaws in the process may be very costly. Solutions to this problem and to improved reliability include an array of techniques and computer-based vision systems. Many of these systems are still under development, and they may prove to be too expensive for the smaller manufacturers.

With ISO 9000 and 14000 registration becoming a significant business, plants manufacturing appearance wood products may consider registration in the future. This involves a significant investment, but experience has shown that, when the exercise is treated as an opportunity to streamline processes, the investment can be recouped quite rapidly through reduced production costs and improved product or service credibility.

See Section 4.18, Overall Quality and Process Control for more details.

Incremental Technological Improvement

- *Develop appropriate on-line scanning and image analysis equipment or other technology to improve detection of defects prior to assembly. Such controls should eliminate defective parts and accumulate a database usable for process control.*
- *Develop and implement an on-line non-destructive quality control system to ensure 100 per cent joint performance and eliminate the need for manual tests.*
- *Develop flow models to minimise in-process inventory.*
- *Develop or adapt computer programs to design and set-up wood machining tools from a sample part supplied by a client.*

Breakthrough Technological Improvement

- *Develop expert systems and decision-aids capable of integrating information collected by the quality control equipment in order to alert operators to problems, and to guide their machine set-up and production decisions.*
- *Develop and implement an integrated process control system incorporating feedback from the various operations as well as economic and market input to automate machine set-up, optimise production in real time, and provide tools and data for simulations and process optimisation decisions.*

CONCLUSIONS FOR APPEARANCE WOOD PRODUCTS

The appearance wood products industry sector has experienced considerable growth over the past 20 years, and it sees itself continuing along the same curve over the coming decade. Market opportunities appear to be plentiful in both the domestic and export markets. Raw materials may be perceived to be scarce by some, but the drive away from commodity production and the appeal of higher returns should free up adequate resources as long as returns justify it. In addition, under-utilised and non-traditional species still represent a major potential resource.

A bigger challenge facing the industry relates to its access to state-of-the-art technology allowing it to compete successfully with other, mostly European, manufacturers, who enjoy the benefits of more experience and the support of a home-grown equipment manufacturing industry. Considering that most Canadian companies in this field are small- to medium-size, ways must be devised to give them access to the technological tools that will ensure their continuing productivity and competitiveness. Opportunities do exist for Canadian equipment manufacturers and service providers to develop equipment, expert systems and other products specifically adapted to the sector's needs, and they should be encouraged to do so.

Advanced technology requires advanced skills, and these cannot be taken for granted by the appearance wood products industry sector. Academic and vocational programs offered by educational institutions will play a critical role in the evolution of this sector, as will computer-based tools and other activities aimed at upgrading staff skills on a permanent basis.

Much like engineered wood products, appearance products derive their higher value from specific attributes that appeal to customers. In other words, they need to be designed to meet dynamic market requirements. Access to up-to-date market intelligence will therefore be a major issue over the coming years.

Design is the key to a direct link between customer and producer, and to value creation. It also represents a critical cultural shift in an industry more familiar with producing components to other people's design. Initiatives need to be undertaken to encourage the development of design as the driving force of the Canadian appearance wood products sector.

9 Preservative-treated Wood Products – Existing and Future Technology

9.1 Introduction and Overview

The treatment of lumber and timbers with wood preservatives to increase their resistance to biodeterioration is almost exclusively done through pressure processes and mature technologies. Chromated copper arsenate (CCA), the dominant wood preservative, has been around for 60 years and the basic vacuum/pressure process has been around for 160 years. Canadian shipments of treated lumber have essentially been stable from 1990 to 1998 at about $400 million; exports, however, increased steadily over the same period (mostly to the US), so that, by 1998, the industry was contributing almost $108 million to Canada's trade surplus.

9.2 Driving Forces

The greatest challenges facing the Canadian treated wood industry are the inability to meet domestic and foreign standards due to the ***impermeability of Canada's wood species*** and the ***restricted range of wood preservatives*** available. The prospect of future ***environmental pressures*** and their effect on **cost competitiveness** are also important issues. These challenges are having an increasing impact on the lumber industry as it finds its potential new markets in the Pacific Rim hampered by ***high termite and decay potential***, and its existing markets threatened by: the spread of the Formosan termite in the US southeast, exacerbated by the withdrawal of effective soil poisons and fumigants; a reduced willingness to spend time on maintenance of structures; and substitute materials that are impervious to termites and decay and need less maintenance than wood.

Wood treatability has always limited the Canadian industry's options in terms of raw materials, as few Canadian species are easy to treat. While incising technology has been a major step forward, it affects appearance and reduces strength. Unless technological solutions are found to enhance the treatability of Canadian species without incising , ***imports of more permeable woods*** may become significant. This problem will also ***limit the ability to export*** treated wood to markets where termites are a threat to wood frame construction.

Exports of treated wood are also limited by the ***inability to use non-chrome, non-arsenical wood preservatives*** requested by customers in Japan and Europe. Such preservatives have been registered in Japan, Europe and the USA for several years, but are still not available in Canada. The range of wood preservatives available in Canada has been restricted by a ***lengthy and costly approval process.***

The chemicals the industry has been using are being ***challenged by pressure groups*** on health and environmental grounds, especially in Europe. In Canada these preservatives have been under intense scrutiny by Environment Canada's Strategic Options Process (SOP) for five years and by the Pest Management Regulatory Agency's (PMRA) re-evaluation process for eight years (completed in 1999). The major impact of the SOP is to require ***upgrading to state-of-the-art pollution minimisation technology*** for all treating plants. Over the long-term, use of oil-type preservatives, such as ***creosote and pentachlorophenol may decline*** due to the increasing cost of oil, and diversion into more valuable end-uses. Alternative oil sources, such as wood waste, could help to alleviate this problem. The use of pentachlorophenol may eventually be restricted as a result of public perception of problems with its dioxin contaminants. Despite lack of evidence of adverse effects, similar public perception problems may eventually result in ***limitations on the use of CCA***.

Low-toxicity preservatives such as borates are not currently capable of replacing conventional preservatives because they are not fixed in the wood, but ***borate-treated wood products*** are likely to find expanding markets where ***termite resistance*** is required.

One vision of high technology wood preservation relies on the ***chemical modification of wood*** as a means of rendering it impervious to natural degradation processes. A technology breakthrough in this area might not meet the economic criteria that would make it applicable to traditional markets for treated wood, but it would open up ***new markets for value-added decorative products***. ***Low-maintenance, durable wood products*** have clearly been identified as having considerable market potential.

9.3 Treatability Enhancement Technology

Existing Technology

The major challenge in treating Canadian species is that most of them have a thin layer of treatable sapwood and a high proportion of non-durable impermeable heartwood. The exceptions are the wide-sapwood species—ponderosa pine and white pine—but these are in limited supply and usually diverted to higher-value end uses. Red pine is also treatable, and it is used for posts, but it is generally unacceptable for decking use due to resin exudation in hot weather.

Canadian and US standards for use of treated lumber (under 125 mm) from thin-sapwood species (spruce-pine-fir and hem-fir) in ground contact require a preservative penetration of 10 mm in 80 per cent of the pieces sampled. This is very difficult to achieve with most Canadian species even with incising. Incisors pass lumber between pairs of toothed rollers that provide a pattern of longitudinal slits facilitating preservative penetration. Incising affects the strength of the wood, requiring reduction factors of 30 per cent for MOR and 10 per cent for MOE in structural applications. Incising also adversely affects the appearance of the treated wood; consequently, unincised lumber is preferred for decking in the marketplace. The use of newer-model fine-sharp-tooth incisors on green lumber, followed by drying can minimise the visual impact, but few treating plants are set up to do this. Some 75 per cent of the treating plants have installed an incisor, but its use is typically limited to relatively heavy lumber and squares.

Needles, lasers and water jets have been investigated for their potential to provide closer-spaced incisions with reduced strength loss and better penetration. None of these technologies has proved practical, economical or sufficiently rapid for industrial application. Biological treatments to improve permeability have also been investigated to a limited extent. Better processes to enhance the permeability of heartwood are required to improve the competitive advantage of Canadian species in the treated wood market.

One simple way to obtain treatable lumber is to sort the more treatable species from the various species mixes. Some treating plants in central Canada preferentially purchase spruce-pine-fir with a high proportion of jack pine, which has long been recognised as a more treatable species. Some treating plants in the interior of British Columbia are now preferentially using subalpine fir that has been pulled from the spruce-pine-fir mix to improve the consistency of kiln drying. Recent work at Forintek has shown that Pacific Silver fir (*Abies amabilis*) is Canada's most treatable thin-sapwood species using current technology; it is the only Canadian thin-sapwood species Canadian treating plants can use reliably to meet treating standards. Several coastal BC sawmills are looking at separating this species from the hem-fir mix and making it available to the treating industry.

The ideal moisture content range for treatment of most species is 25 to 30 per cent, where the sapwood cells are empty of sap, but the pathways between the cells have not been sealed shut. On the other hand, where wood is treated green there is a greater differential between treated moisture content and equilibrium moisture content, causing increased checking which may allow entry of fungal spores to untreated wood. Only 30 to 40 per cent of treating plants have their own kilns, and sawmills are unwilling to dry specific batches to a higher target moisture content. Regular kiln-dried lumber typically contains a proportion that is too dry (hence impermeable) for treating. Various pre-treatment drying regimes incorporating steam or vacuum have been investigated, but none have been able to significantly improve permeability. In green lumber, the sapwood is full of water and cannot be adequately treated; nevertheless, some treating plants still try to treat green lumber.

Most of Canada's 67 treating plants are stand-alone operations, but at least 9 are integrated with sawmills. The latter have some advantages in their ability to select the more treatable species from their species mix and dry them to ideal moisture contents for treatment. However, these opportunities have not typically been exploited.

Incremental Technological Improvement

- *Identify Canadian wood species or variants possessing above-average permeability to current treating solutions.*
- *Pursue the development and implementation of species sorting technology to facilitate access to the more treatable species.*
- *Investigate processes to stabilise red pine resin and inhibit exudation.*
- *Pursue the development of second-generation incising technology for improved product appearance and treatment efficiency*

Breakthrough Technological Improvement

- *Develop cost-effective biological treatments to improve the permeability of Canadian thin-sapwood species.*

9.4 Preservative Technology

Existing Technology

Chromated copper arsenate (CCA), patented in1934, is a highly effective preservative. It fixes within the cell walls, leaving only trace amounts in a mobile form within the wood. It protects against decay, termites, marine borers and ultra-violet light. Water repellents can be added to the CCA formulation to improve resistance to checking caused by wetting and drying cycles. CCA has an excellent dose response, meaning that larger loadings of this preservative result in a longer service life under a given condition.

Some critics consider that CCA may cause adverse environmental and health effects. The available data has been exhaustively reviewed by the US Environmental Protection Agency (EPA) and the Pest Management Regulatory Agency in Canada, and the results will be announced in July 2001. Preliminary indications are that CCA will continue to be available to industry.

Ammoniacal copper zinc arsenate (ACZA) has recently been introduced into Canada as a substitute for ammoniacal copper arsenate (ACA). Only one Canadian treating plant is using this preservative, primarily for marine applications and large timbers. ACZA penetrates Douglas-fir much better than CCA because of the solvent characteristics of the ammonia.

Pentachlorophenol in heavy oil is still used for utility poles by a few utilities in central Canada and creosote is still used for railroad ties. In statistical data, creosote is the preservative with the largest volume used, but this is because creosote loadings are in the region of 25 to 30 per cent by weight of wood whereas CCA loadings are in the region of 1 to 3 per cent by weight of wood.

A number of non-arsenical non-chromium preservatives have been introduced in other parts of the world. These typically contain copper ethanolamine plus an organic co-biocide with low mammalian toxicity. Examples are amine copper quat (ACQ) and copper boron azole (CBA). Europe and Japan have used both for a few years, and ACQ has also been used in the US. Neither preservative is currently used by Canadian treating plants. These preservatives are not as well fixed and stable in wood as CCA and they do not have a long track record. They are also considerably more expensive than CCA. A number of purely organic biocides are also under development. While these are even more expensive, they are typically only used in small amounts. Currently, their major advantage is also their major disadvantage: they are biodegradable in soil, but may also biodegrade in wood.

Preservatives based on sodium borate are not currently capable of replacing the fixed-copper or oil-type preservatives because they are not fixed in the wood. Borates have recently been re-introduced in Canada, intended primarily for export markets where termite resistance is important. However, in the Vancouver area, much of the initial production has been used for re-construction of framing that has decayed as a result of moisture leakage through the building envelope. Borates have a number of advantages in that they are effective against decay, termites, wood-boring beetles (and fire at higher loadings). they are also colourless, odourless, inexpensive and have very low mammalian toxicity. They are also diffusible, which means they can be applied to green lumber and will ultimately penetrate the full cross-section. The major disadvantage of borates is that they are not fixed in the wood; consequently they are only suitable, at present, for use in applications protected from continuous contact with liquid water. The fixation of borates has been attempted by a number of laboratories around the world, but no practical solution has yet been identified.

If necessary, the industry will adopt the amine copper organic co-biocide systems and then cocktails of organics, but the rate of change will be determined by consumer demand and the resulting response from regulatory bodies. Even under this scenario, CCA could be retained for structural products with a high consequence of failure, such as utility poles. Environmental issues are further considered in Section 9.7, Pollution Abatement Technology.

Wood modification, chemically or physically altering wood to make it biodeterioration- and weather-resistant without the use of biocides, is the ideal goal. A number of chemical processes have been developed, but none have proved cost-effective enough to commercialise. Physical treatments using heat in the absence of oxygen have shown some promise, but they do not seem to meet the performance claims made for them; they also reduce the strength of wood. These processes are relatively complex and expensive and process details are kept confidential by the companies involved. More cost-effective wood modification processes could eliminate environmental and health concerns.

Incremental Technological Improvement

- *Identify preservation chemicals having low mammalian toxicity and low environmental impact.*
- *Continue developing methods allowing for more rapid evaluation of new treating chemicals compared to longer-term field tests.*

Breakthrough Technological Improvement

- *Identify a cost-effective technique to fix borates in wood without affecting its wood preservation potential.*
- *Develop a cost-effective combinations of targeted organic biocides that are stable in wood, biodegrade in soil and burn without generating toxic fumes or ash.*
- *Develop a cost-effective process to chemically or physically modify wood in order to make it resistant to UV light, biodegradation and dimensional changes, yet without affecting its appearance or its mechanical properties.*
- *Apply the resources of genetic engineering to create trees capable of producing wood with acceptable mechanical properties and natural resistance to biodegradation.*

9.5 Fire Retardant Technology

Very little fire retardant treatment is done in Canada, because the use of fire-retardant treated wood is not favoured by the building codes. Most of the fire retardants currently available are combinations of nitrogen, phosphorous and boron compounds. Nitrogen and phosphorous are nutrients for fungal growth, which makes it difficult to develop treatments combining fire retardant and wood preservative properties for exterior applications. Some work toward such a product has been done, but the product has not been commercialised. There is one combined fire retardant and wood preservative for interior use that is a combination of guanyl urea phosphate and boric acid.

9.6 Treatment Process Technology

Existing Technology

The vacuum/pressure process used in all Canadian plants treating with CCA is the full-cell, or Bethell, process patented in 1838 and virtually unchanged since that time. It consists of an initial vacuum (typically 60cm of mercury) of around 30 minutes, a pressure period (typically 1035 kPa) of an hour or more and a final vacuum of around 15 minutes. Plants treating with creosote and pentachlorophenol in oil use an empty–cell, or Lowry, process with no initial vacuum. Most treating plants have some form of electronic control via programmable logic controllers, and an increasing number are fully computer-controlled. In the conventional variable cycle, pressure is raised to its target level, then allowed to drop as the wood absorbs the solution; when the pressure drops to a specified low point (typically 860 kPa), it is raised back to its target level. The cycle continues until the desired uptake is achieved. A variety of modifications to this basic process have been investigated, including oscillating pressure, alternating pressure and pulsation processes. None of these has proved sufficiently effective to warrant commercial application in Canada. Pressures higher than 1035 kPa can cause collapse in some species, but modifications to the treating process may be able to overcome this problem. The use of control valves to maintain a uniformly high pressure has been around for at least 15 years and is used in 45 per cent of treating plants in Canada. This process has recently been demonstrated to provide superior penetration compared to the variable pressure cycle. Further improvements in this technology are possible.

The ability of treating solutions to penetrate wood is limited by their viscosity. One way to provide a major improvement in penetration is to go to supercritical fluid or vapour phase processes. This generally also means a change in the preservatives used since the currently registered preservatives do not lend themselves to these new processes. Supercritical fluid treatment is under investigation at Oregon State University. Vapour phase borate treatment (still non-fixed) is being commercialised in the UK and similar processes have been developed in Japan. Major impediments include the requirement to dry wood to very low moisture contents, resulting in increased drying defects. Nevertheless, this is a promising area for research in Canada.

Pre-staining of lumber prior to pressure treatment has allowed the industry to provide a range of factory colours on its CCA-treated product. Most common are browns, reminiscent of western red cedar, and greys that give a pre-weathered appearance. When dry, CCA-treated wood can also be painted or stained, and the chromium component enhances the performance of surface finishes by protecting the wood against UV damage.

Incremental Technological Improvement

- *Modify current treating processes to improve preservative penetration.*

Breakthrough Technological Improvement

- *Develop vapour phase treatment processes incorporating new biocides/wood modification agents.*

9.7 Pollution Abatement Technology

Existing Technology

Many of Canada's treating plants have already been upgraded to meet the requirements of Environment Canada's Technical Recommendations Documents for the design and operation of treatment plants issued in 1988. These have recently been condensed into one document, "Recommendations for the Design and Operation of Preservation Facilities" (Environment Canada, 1997). This document outlines all the available technologies and procedures for minimising occupational exposure, health risks from the product and adverse environmental impact. All treating plants are expected to be in compliance by 2005. Additional measures for new concrete pads and foundations include plastic liners, monitoring wells and flushing systems. Rather than avoiding contamination limits on arsenic in storm-water runoff by changing preservatives, Canadian treaters have put plant modifications, procedures and processes in place to meet these limits. One reason for this is that the alternatives to CCA all contain more copper, which is particularly toxic to aquatic life, and storm-water limits for copper are also stringent.

One outcome of the current regulatory scrutiny of CCA is mandatory testing to confirm that the fixation process is complete before the lumber leaves the treating plant. This is already a requirement of CSA O80 Series 97 Wood Preservation. Fixation is a time- and temperature-dependant process, and can be an impediment to timely delivery of product during much of the year in Canada. Some 25 to 30 per cent of the treating plants are equipped with accelerated fixation chambers (modified kilns or heat boxes). This proportion is expected to increase rapidly since confirmation of fixation is required in the Technical Recommendations. The accelerated fixation process for CCA applies heat (50°C or higher) to the lumber for periods of several hours depending on the temperature and the efficiency of the heat-transfer medium—air, water or steam. Kiln drying after treatment is only required for permanent wood foundations (PWF) and lumber or plywood intended for repairing decay in buildings. Most treated product is shipped in the wet, but fixed, condition.

Considerable amounts of capital have been expended on pollution abatement in Canada. Typical projects include extending the paving of plant operating areas, epoxy coating of concrete surfaces, dedicated on-pad and off-pad forklifts, covered storage areas for freshly treated wood, enhanced kick-back and drip recovery systems, accelerated fixation chambers, and storage tanks for contaminated rainwater.

The Canadian Institute of Treated Wood and the Western Wood Preservers Institute developed the Best Management Practices for the Use of Treated Wood in Aquatic Environments in response to concerns raised by the users of treated wood. Processes and procedures for minimising migration or leaching of preservative into the environment are specified for all registered preservatives. The recommendations include: ensuring that wood entering the retort is free from residues that could absorb preservative and subsequently slough off; use of a post-treatment expansion and steaming bath for creosote; minimising over-treatment; verifying fixation for CCA; and inspecting for surface deposits prior to shipment.

Environment Canada has developed a list of potentially toxic chemicals in industrial use and is in the process of assessing their hazard to the environment. It is developing options for reducing the risk of adverse environmental impact. The wood preservation industry is considered to be one sector that uses several of the chemicals on the list, including arsenicals (incorporating chrome VI), poly-aromatic hydrocarbons (from creosote), and dioxins (as contaminants of pentachlorophenol). The Toxic Substances Management Policy divides the types of options into Track 1 and Track 2. Track 1 means virtual elimination of releases to the environment and is designed for toxic substances that are manufactured, persistent and bio-accumulative. Track 2 means cradle-to-grave management to minimise risks by reducing human exposure to, and release to the environment of, other substances of concern. The goals for Track 2 will be based on a balance of health, scientific, technical and socio-economic realities in a manner consistent with sustainable development. Since arsenic is a by-product of the purification of metallic ores, and creosote is a by-product of coke production, these are not considered to be deliberately manufactured. All three preservatives have been allocated to Track 2. Pollution prevention is a key goal. Risk reduction measures rely heavily on the Recommendation Document for the Design and Operation of Preservation Facilities and the Best Management Practices for the Use of Treated Wood in Aquatic Environments.

Current methods of disposal of treated wood at the end of its service life may be considered to constitute a release of preservative to the environment. Further research into methods for recycling preservative-treated wood is therefore warranted. Currently between 50 and 100 per cent of utility poles removed from service are re-used or recycled. Disposal of consumer lumber has not become a problem as yet. Landfill of treated wood is permitted at landfill sites where untreated wood is allowed, but space and cost considerations may rule this option out in the future.

In the near future, cradle-to-grave responsibility for wood preservatives will be put into practice and methods for recycling preservative treated wood will likely become commercially available in the next few years. At that point, treated wood will truly be considered alongside untreated wood as a renewable resource

Incremental Technological Innovation

- *Develop applications for recycled preservative treated wood.*
- *Develop processes to recover treating chemicals such as creosote or pentachlorophenol from recycled treated wood.*

CONCLUSIONS FOR TREATED WOOD PRODUCTS

The Canadian treated wood products industry has experienced zero growth in recent years, partly because it has had to spend much of its energy on environmental issues, partly due to limited promotion. A mature commodity market has led to heavy price competition and little profit margin available for investment in research or promotion. The growing strength of wood-based value-added products may create new opportunities in the area of consumer products, provided technological improvements allow the industry to improve treatment quality while maintaining or reducing costs.

Technological breakthroughs have been identified that have the potential to open up new markets and free the industry of its public perception problems. Research in the technologies involved should be seen as an essential investment as it would position the Canadian industry for a much-needed re-launch with of families of durable wood-based products.

10 BREAKTHROUGH TECHNOLOGIES

Throughout the previous sections of this report, breakthroughs have been identified, each of them with the potential to achieve significant gains for the Canadian wood products industry. They vary in scope: some of them would benefit most sectors, while others might relate to a narrower field. They also vary with respect to potential impact and risks involved. Breakthroughs, as defined in this series of Roadmaps, carry no guarantee of technical success; the very fact that they were suggested by contributors to this study indicates that there are reasons to believe in their technical feasibility. They still, however, require a major commitment by the wood industry and its R&D partners, as well as a sustained effort by all stakeholders over the longer term.

The potential technological innovations presented in this chapter are only a sample of those identified in the report. The list is not exhaustive, nor does it imply priorities, which, in any event, should be left to more focused regional or industry groups. Recommendations are made in the next chapter as to the setting of priorities and the development of action plans.

Beyond technical success, breakthroughs also need to be economically feasible. Innovative concepts may be killed by the premature application of narrow-minded economic filters, and it is recognised that scientific innovation should enjoy a degree of freedom; however, as concepts turn into processes, economic feasibility needs to become one of the critical criteria. Perhaps, one breakthrough would consist in providing scientific and industry personnel involved in product or process development with more sophisticated tools to apply progressively tighter economic guidelines as projects firm up.

Research institutions will naturally be expected to play a critical role in the development and demonstration of these technological breakthroughs, but successful implementation in the Canadian industry's plants will require collaboration of all parties, including primary and secondary manufacturers, equipment manufacturers, software suppliers, and engineering consultants, within the framework of a permanent partnership.

An integrated approach is a necessary condition to successful development, in part because all machining centres are interdependent and must be considered as a system, and in part because, beyond return on investment, success will be measured in terms of client satisfaction, value recovery, environmental impact, health and safety, job quality, etc. This is true, of course, for all sectors, but it takes on a greater degree of urgency in the context of engineered wood products (EWP) and other value-added products.

As identified in the Driving Forces sections, the Canadian wood industry's success over the next decade will depend to a large extent on its ability to become a knowledge-base industry. Many of the potential technologies listed below relate to the acquisition and analysis of information: mostly technical information (e.g., log and lumber characteristics), but also information regarding markets, economics, equipment, etc., so that production decisions may be made from the vantage point of an integrated knowledge base.

Even in the primary sector, flexibility will be a major asset, and the only path to increased client focus that does not sacrifice productivity and economies of scale runs through process control, initially with the development of expert systems and other decision-aid tools. The ultimate goal is moving to a form of totally integrated process control that will give managers the power to respond to market opportunities and value optimisation without losing sight of other factors, particularly cost control.

1. Image processing to analyse forest stands and characterise the resource (primary sector)

More specific information on forest stands (e.g., species distribution, stand density, health characteristics, stem diameters) would allow managers to make better decisions regarding forest management, basic log allocation, and log processing. Such information would serve to create comprehensive databases on resource categories, which would then serve as input in various models. It could also be supplemented with data collected automatically during thinning or logging operations, possibly with the assistance of scanners mounted on logging equipment.

Technology such as that developed for military applications, employing high-resolution photography from satellites or aircraft and computer-assisted image analysis, might be adapted to this purpose.

2. Supply chain utilisation system to integrate all supply inputs (all sectors)

Management decisions in the wood industry are typically difficult to make because they involve many complex factors, ranging from stand characteristics to client preferences, and including available capital or human skills, equipment characteristics, environmental impact, distribution systems, marketing strategies, etc. In practice, a number of these factors are frequently overlooked, and decision quality is limited by the managers' personal knowledge.

Supply chain management and optimisation tools already applied in other industries need to be adapted to the wood product industry.

3. External and internal scanning techniques for logs and lumber (all sectors)

Comprehensive information on log characteristics is a condition of value optimisation. While current scanners provide data on the shape of the log, and technology is under development to assess internal characteristics on the basis of external ones, only through-the-log scanning will yield accurate data for bucking and primary sawing decisions. Several scanning techniques may have to be combined to provide a full picture of the log under bark and after debarking. In a similar fashion, internal scanning of lumber would allow for better edging and trimming decisions by detecting geometry defects and other surface defects (decay, knots, splits, specks, etc.) at industrial speeds, providing data to integrated models for computer-aided decisions in real time. In secondary manufacturing operations, internal scanners could also be used for improved "defecting" prior to finger-jointing, for example, or to scan hardwoods for remanufacturing. The equipment should be capable of evolving on the basis of its own experience ("neural" networks).

As discussed in Section 4.7, various types of scanning systems have been proposed. At this point, however, none appears to be capable of operating at industrial speed. With solutions involving multi-sensor systems, cost-effectiveness is also likely to be a major challenge, especially if the equipment is to be used in mills processing small logs. Computing power will need to handle large amounts of data, especially if the scanning operation is linked to a variety of optimisers, both upstream and downstream.

4. Automatic identification of individual softwood species (softwood lumber industry)

The search for maximum product value includes identification of individual species in commercial species groups (e.g., hem-fir, spruce-pine-fir) so they may be processed in the most suitable manner. For example, mills want to segregate out alpine fir and balsam fir in order to dry them under different schedules. Others may want to sort out jack pine or Pacific fir to take advantage of their relative permeability to preservative treatment. Still others want to pull out pines for remanufacturing operations. In every case, species segregation is required to optimise the process (reduce costs) or the end-product (enhance value). At this stage, this is mostly done manually. Full automation of the species recognition in the green and dry lumber state would allow error-free sorting at high production speed, with possible applications at various locations in the mill depending on the objectives pursued.

The required systems should be able to identify a variety of wood species under a broad range of operating conditions (including weather), and should not be affected by surface characteristics of the wood.

5. *Smart debarking system to optimise lumber recovery and chip quality (primary sector)*

Existing debarking systems remove bark by pressing knives against the log. Although they are capable of yielding acceptable results when properly adjusted and maintained, they are not very effective when dealing with frozen or misshapen logs.

A smart debarking system might combine a true-shape scanner to determine the shape of the log under the bark, and a shaper-like tool to remove bark under computer control.

6. *Technology to sort lumber into categories of comparable dryability (all sectors)*

Mills trying to optimise drying time and lumber quality have been turning to lumber sorting as a means of creating more homogeneous kiln loads. Common sorting criteria include size, species, initial moisture content and weight, either alone or in combinations. While these factors are known to have a bearing on the drying characteristics of wood (i.e., its "dryability"), they are not sufficient to predict drying behaviour with a high level of precision. Some of the factors involved are known and measurable while others are not yet measurable (e.g., growth rate, permeability), or even identified.

Before products can be sorted into groups of equal dryability, all factors affecting drying behaviour need to be identified and evaluated as to relative significance. The next step will consist of developing the necessary technology to measure all significant factors in green lumber (primary production) or dry lumber (re-drying for value-added operations), and integrating the data thus obtained into a computer-based model capable of developing the most economical groups on a continuous basis. Existing models such as OASiS would probably serve as a basis for such a model.

7. *Computer-assisted vision systems to automate quality control and wood matching operations (lumber and value-added products)*

Computer-assisted vision systems are already in use in some grading systems, and this technology has been evolving quite rapidly in recent years. In a sawmill environment, a breakthrough would consist of applying vision technology to the evaluation of products immediately after each processing operations in order to assess quality and provide feed-back. For example, size and surface quality information collected after sawing operations could be fed back to millwrights and to saw-filers. The information thus collected could also serve as input for automated process control as discussed below.

In the production of finger-jointed lumber, vision systems might be developed to provide a cost-effective way of measuring profile deviations (including off-square cuts and broken fingers) as well as adhesive application.

In the production of appearance products, vision systems can serve to match wood grain and colour in finger-jointing or edge-jointing operations. Systems are currently available to perform this type of operation, but a breakthrough is needed to turn them into cost-effective, flexible machines, capable of high production rates. Highly efficient systems rely on combinations of vision principles, and success will depend in part on the availability of high capacity computers to handle the large volumes of information involved.

8. *Automation of equipment adjustment and tool changes (all sectors)*

The adjustment of saws, planers or other equipment and the replacement of saw-blades and knives is a problem in the lumber industry because of the down-time involved and the precision demanded by high-recovery objectives. The expected emphasis on quality and multiplication of product specifications over the coming years will make this an increasingly critical issue.

A breakthrough in this area would consist of adapting to a variety of wood machining centres technology currently used in the appearance product sector, where robot-like machines can read CAD drawings, select the tools required to do the job and adjust themselves according to the dimensions and details of the part to be manufactured while controlling infeed and outfeed.

9. Kiln controller to optimise drying cycle for individual load and exterior characteristics (all sectors)

Cost control and quality optimisation both require that drying conditions be specifically adjusted to: the characteristics of the load in the kiln (i.e., its overall dryability), factors affecting drying effectiveness (e.g., kiln characteristics, energy input, air flow characteristics), and mill objectives (e.g., average moisture content, moisture content gradient, economics of degrade). As a number of these factors change continuously during the drying cycle, effective drying demands on-going measurement of critical parameters inside the kiln.

Further model development is required, in addition to a major effort to define and quantify all significant input and output parameters. As technology evolves towards fully automatic kiln control, it would in the meantime produce a powerful decision-aid tool for kiln operators and quality control personnel.

10. Integrated systems to grade wood products on-line (softwood lumber and EWP)

While technology is available to evaluate some mechanical properties of lumber, others, such as stiffness on edge, axial properties and shear resistance are calculated through correlation equations. Since correlations are necessarily derived from large quantities of data and bolstered by safety factors, individual lumber pieces cannot be optimised for applications where performance is controlled by one of the calculated factors.

In the case of engineered wood products, very little equipment is available for on-line quality control, and the industry has to rely on limited off-line tests to support quality assurance programs. Such tests are costly, and problems may not be detected for several hours.

Existing vision-based systems can measure geometry-related defects (e.g., size deviation, wane, skip), but not decay, knots, speck, etc., and these have to handled by graders.

Fully-integrated grading systems would provide reliability and allow for accurate grading to a large number of changing rules. Such systems would involve combinations of evaluation methods selected according to product and critical criteria; they would rely on a computer-based program integrating market and economic information. In addition to controlling the actual grading operation, they could be linked to a mill's central computer and used for simulations and the evaluation of scenarios.

11. Expert systems and simulators to transfer technology to managers and operators (all sectors)

As production technology becomes more sophisticated in sawmills and remanufacturing operations, it becomes increasingly difficult for managers and operators to master its potential, adapt it to their specific conditions and provide useful feed-back to equipment and software suppliers. In addition, data acquisition and information technologies are evolving so fast that skills need to be continuously updated.

Although automation may appear to be a solution to some of these problems, it does have its limitations, particularly when it makes mills more dependent on outside resources.

Computer-based simulators serve to train staff efficiently off-line, shortening the learning curve and reducing the impact of training on throughput and quality. Some simulators are available, but they should become a cost-effective tool available to most mills.

Expert systems have been used in other domains, such as the medical field, as a means of extending an operator's knowledge and experience by giving him/her access to the knowledge and experience of others. Expert systems can also be organised in such a way as to transfer advanced technology in relatively simple terms.

Simulators and expert systems should not be seen as substitutes for proper education and training, but rather as tools complementing basic knowledge.

12. Integrated on-line quality control and process control (all sectors)

Various quality control methods, including those based on vision systems, can be used to evaluate product characteristics immediately after each machining centre in order to detect and reject defective parts. When the data generated by such quality control systems is analysed, it can serve to detect trends and biases in manufacturing equipment, and alert staff accordingly. For example, information on moisture content variations and defect characteristics collected at the grading station should be fed back to the kiln and the sawmill.

Processed quality control data can also be used to automatically correct problems if technology is available to automatically adjust equipment. It can also contribute to a preventive maintenance program.

In a fully-integrated process control system, all machine centres are linked to a central computer responsible for monitoring quality and production levels throughout the mill, co-ordinating machining centres for optimum flow and throughput, detecting trends and correcting problems whenever feasible and proposing the best alternative solution when the best solution is not available (e.g., a conveyor is jammed). The central computer program optimises operations for manufacturing and other factors selected by management, such as market opportunity, economics, corporate objectives, etc.

Given the complexity of the lumber manufacturing process, full process control integration may not be accessible within the 10-year timeframe considered in this report, but it should nevertheless be considered as an ultimate goal, and steps taken to gradually implement it.

13. Commercial products to turn bark from a liability into an asset (primary sector)

Work is being done to utilise more bark and other by-products as a fuel in fuel-cells or other energy systems. Technology is also under development to use bark as the raw material in a durable panel with apparent economic potential.

Given the extremely large volumes of bark available throughout Canada, it is unlikely, however, that these processes will deal with all of it, and there seems to be room for other economic applications for bark (as opposed to disposal solutions). Breakthroughs are needed to identify and develop value-generating commercial products or processes that would benefit from the unique properties of bark.

14. Application of synthetic fibres to the reinforcement of engineered wood products (EWP)

The availability and continuing improvement of high performance synthetic fibres such as polycarbonates have created opportunities for the development of improved engineered wood products. Synthetic fibres are already being used effectively to increase the practical span of glulam products.

An opportunity exists to systematically examine the potential of fibre reinforced products (FRP) in the design of existing engineered wood products (e.g., finger-jointed lumber, trusses) or new ones. The objectives could be to enhance product performance characteristics or to reduce manufacturing cost.

15. Adhesives for reduced manufacturing costs and improved performance (value-added products)

Traditional adhesives used in structural applications typically represent a significant cost factor. In many cases, curing is either a slow process, causing the build-up of an inventory, or it requires energy. In the manufacture of both engineered and appearance wood products, methods used to make adhesives more reactive tend to decrease the time available for using them (shelf-life), increasing the risk of quality problems.

Breakthroughs are needed in the development of stable adhesives capable of reacting rapidly through some form of a trigger mechanism. The formulation of such adhesives should be readily adjustable to specific conditions of wood species, moisture content, surface characteristics, desired speed of reaction and desired performance, including immediate bond strength, moisture resistance, long-term creep and other criteria, depending on applications. Since structural glued products need to meet specific mechanical criteria, methods have to be developed to evaluate new formulations and provide guarantees of short- and long-term performance.

16. Powder coatings to eliminate solvents in the finishing of appearance wood products (appearance wood products)

While powder coatings have been used successfully in other industries, results with wood products have not yet warranted commercial development, essentially because wood (especially dry wood) is a poor conductor of electricity.

Given that powder coatings represent a major step forward in eliminating all solvents (including grain-raising water) as well reducing waste and air contamination in the furniture industry and other sectors producing appearance products, breakthrough technological innovation to solve this problem in a cost-effective manner would have far-reaching effects.

17. Finishing system for no-maintenance exterior wood products (appearance wood products)

The need repaint or otherwise refinish wood products at regular intervals has been identified as a major factor in the success of competing materials such as plastics and metals in displacing wood in some exterior applications like outdoor furniture, siding, trim, etc. Long-lasting performance has been achieved with some solid-stained siding products, but no practical solution has yet been proposed to provide protection from UV and moisture degradation while maintaining the natural appearance of wood (and its traditional appeal to customers).

Innovation in this area might involve the identification and development of a cost-effective process to chemically or physically modify wood without affecting its appearance or mechanical properties.

18. Biological treatments to improve the treatability of Canadian wood products (treated wood products)

Biological treatments have been identified as having some potential to degrade cell structures that interfere with wood permeability without the side effects of incising (i.e., impact on appearance and mechanical properties).

Since biological treatments usually require specific conditions of temperature and moisture, in addition to being relatively slow, the challenge is to identify process conditions likely to be economically feasible and compatible with the requirements of a normal industrial operation.

19. *Genetic engineering to produce naturally durable wood products*

Naturally durable wood species, such as cedar, have retained their consumer appeal over the years in spite of competition from treated wood products, plastics and metal. Recent achievements in genetic engineering suggest that it might be feasible to transfer genetic material responsible for the natural durability of cedar or other species (not necessarily limited to wood) to other, abundant and fast-growing wood species such as pines, spruce or aspen.

A breakthrough in this application would obviously have no impact in the short-term, but it would dramatically change the competitive position of wood in the long-term.

20. *New products*

As demonstrated by the rapid growth of the secondary (value-added) industry, and discussed in the Driving Forces sections of this report, various factors combine to encourage the Canadian wood industry to develop new products, either to diversify production when commodities suffer from intense competition, as a way of compensating for restrictions in wood supply, or as a means of adding value to existing product lines by accessing niche markets.

While countless new products can be obtained through adjustments to cutting and finishing systems, breakthroughs will come from significant modifications of wood properties, such as chemical, physical or even genetic processes as discussed above. This will particularly be the case for appearance products, but a major breakthrough for this sector of the industry would be to adopt design as a vehicle to match market requirements and product specifications.

Breakthroughs in the structural product sector will also come from the innovative combination of wood components and other materials (e.g., metal, adhesives, synthetic fibres, plastics) designed to achieve specific attributes required by the market place. In most situations, however, structural products are used as part of a system, and the performance characteristics of the system (e.g., fire resistance, durability, structural integrity, final cost) are far more important than those of its individual components. Breakthrough technological innovation in this domain involves the design of systems against desired performance criteria (i.e., market requirements, and the design of wood-based products best suited to these systems.

In Conclusion...

As demonstrated by this sample list, many opportunities exist to solve some of the challenges currently facing the Canadian wood industry, and to open up new opportunities for development. Breakthroughs in other sectors, especially computer science, provide powerful tools to tackle technological difficulties that may have sounded insurmountable only a few years ago. Attitudes have also changed, and there is more willingness to innovate, even when a degree of risk is involved. As the technological and economic background continues to evolve, so does the potential for breakthrough innovation, and any R&D plan should include a watching brief over developments in other industries.

Cost-effectiveness has been mentioned repeatedly in this section, mostly because, in many situations, implementation of a cost-effective solution is the major part of the challenge. This is particularly true with smaller operations (e.g., value-added sector), where high price, high volume equipment is not an option.

Recommendations are made in the next section to create an infrastructure favourable to the development of a knowledge-based, technology-oriented wood industry, which would also create ideal conditions for the potential breakthroughs identified above to radically improve the competitive position of the industry.

11 RECOMMENDATIONS AND ACTION PLAN

Canada has traditionally enjoyed a relative abundance of raw materials, which it has used to develop its enviable export capacity. Canadian softwood lumber manufacturers have generally kept up to date on new technology, and in some sectors they have developed into world leaders. The big challenge for this industry, as it is for so many other Canadian exporters, is to maintain its advantage in the face of a deteriorating wood supply situation, restrictions to trade and increasing competition from foreign producers and non-wood building materials. The industry must become even more competitive in manufacturing commodity products, while acquiring new skills with respect to market specialisation and production flexibility.

In the hardwood sector, a number of plants have developed know-how and marketing skills on the basis of imported logs. For the majority, however, the major challenge is to obtain products with the right attributes from a variety of non-traditional logs or non-traditional species. This has led many of the producers to move into value-added products, especially furniture parts and other appearance products, and they now have to find profitable applications for their low-grade lumber, or adopt new technology to upgrade it. The hardwood industry has not been as technology-intensive as its softwood counterpart, and, given its structure and economics, its needs will continue to be different. It also has to refine its marketing skills, diversify its product range, and optimise its production methods.

For the same reasons that the hardwood industry has been moving into appearance products, the softwood industry has shown increasing interest in engineered wood products. With more and more large players now producing MSR and finger-jointed lumber, what used to be value-added products are fast becoming commodities, and producers already emphasise reduced production costs rather than higher market value. Innovation will be needed to maintain the momentum and protect profits.

Increasing interest in value-added production by the wood industry and by new entrepreneurs has spawned a new industry sector characterised by fast growth, small- to medium-size companies, high employment (in relative terms), a great diversity of products)both structural and appearance), a need for technological and other skills, and, unfortunately, a high rate of failure. Although volumes in this sector do not even approach those of the primary sector, the remanufacturing and value-added industry is perceived by many as the chrysalis of a design-based industry with great export and profit potential.

The following recommendations extend beyond technical issues, because technology alone cannot guarantee the industry's success. They particularly emphasise technology transfer, access to information, technology updates and training because the lumber industry's most urgent problem tends to be its ability to use technology, rather than the availability of technology. In addition to ensuring that the industry remains cost-competitive, technology also has to be integrated into clear longer-term strategies which include human and material resources, dynamic and prospective market intelligence, and a sensitivity to predominant social factors in both producing and consuming regions.

Each set of recommendations is meant to be self-supporting. As all recommendations necessarily overlap to form a coherent strategy, this results in a degree of repetition.

Given the strategic nature of the following recommendations, it should not come as a surprise that many of them are identical or very similar to those contained in Industry Canada's *Technology Roadmap on Wood-based Panel Products*.

STRATEGIC PLANNING

1. Develop long-term R&D programs

The R&D program needs to be the next step in the roadmap. It should be set out in broad terms initially, and designed to achieve the industry's medium- and long-term priorities. Research programs already supported by industry, the Canadian federal government and several provincial governments constitute an excellent starting point. Much is already being done at universities and industry's research institutions, and the aim should be to reinforce and streamline this effort rather than duplicate it.

A number of breakthrough technologies have been identified in this report. By definition, these are high-risk high pay-off undertakings which would go a long way in ensuring the industry's success. They should be further evaluated, prioritized, and translated into a series of manageable R&D goals and projects adapted to regional or sectoral needs.

Incremental technology innovation may be more dependent on equipment manufacturers or other suppliers than on R&D institutions, but the latter have a role to play in providing the basic information that evolving technology is using—evaluating new technology and integrating all processing and marketing centres into a coherent system. With respect to structural products, R&D institutions also play a critical role in facilitating market access through codes and standards.

Fundamental research on wood characteristics, drying, machining, gluing, finishing, etc. should form part of the program. Neglecting it might jeopardise the industry's ability to pursue process optimisation and control. Research also needs to address the issue of design (see below) in both the structural and the non-structural sectors. Design, which translates customer needs into products (and occasionally precedes actual needs), should be seen as the guide to all value-added programs and to product development.

R&D programs should include the development of economic evaluation and decision-aid tools to be used by research and industry to benchmark existing technology and predict the impact of new technology. Such tools should eventually be integrated into process control and management programs. R&D programs should be linked intimately to market development plans (see below) in an interactive fashion, and support the delivery of short-term gains at the same time that they pursue their more ambitious objectives.

Responsibility: industry, industry associations, industry suppliers, research institutions, governments

2. Reinforce existing industry advisory committees to guide implementation of the industry's R&D program

Existing industry advisory committees play a critical role in ensuring that the R&D programs serve industry's interests, and in facilitating implementation of these programs. While R&D institutions and universities have no monopoly over innovation, they are in the most favourable position to provide the basic knowledge without which progress can only be empirical and slow. They can assist with the development and implementation of incremental technologies, and they are best equipped to explore and test breakthrough technologies.

Research programs need the guidance of the lumber industry they are serving, but they also need input from equipment suppliers, engineering consultants, and all other stakeholders. Mechanisms need to be found to give these partners a voice on advisory committees without disrupting existing arrangements. A technology watch also needs to be instituted over technical developments in industries other than wood, to identify techniques which could be adapted to this industry.

Federal and provincial government agencies need to participate actively with industry on advisory committees to ensure that the programs serve provincial and national objectives in the most coherent manner, and that stable funding is available to support them.

Shared risk/shared profit has proved a successful formula in existing R&D efforts. However, current programs fail to provide adequate means to demonstrate innovative technology on an industrial or pre-industrial scale, and the stakeholders should consider how the shared risk/shared profit philosophy could be extended to this essential phase in technology implementation. Appropriate business analysis techniques should be identified for long- and medium-term R&D projects, and applied to the industry's research initiatives in order to facilitate prioritisation of decisions.

Responsibility: industry, industry associations, research institutions, industry suppliers, governments

3. Continue supporting industry's R&D efforts

In order to develop the technology that industry requires for its continuing success, and to help it become or remain a world leader as a provider of high-value products, research institutions, industry laboratories, and universities need long-term commitments to direct and indirect funding from industry and governments. This is essential to attracting and retaining the highly specialised skills necessary to carry out the research and transfer its results to industry.

Technology development and applied research need to be sustained by an understanding of principles involved, and this understanding comes only through fundamental research. Current trends, which see universities and research institutions neglect fundamental research in favour of more profitable activities, may be dictated by economic necessity, but they represent a threat to continuing R&D and, indirectly, to the Canadian wood industry.

Government funding of research is more likely to serve national and industry goals if the various government programs are crafted to be complementary, and if the funds are primarily used to support co-ordinated multi-partner programs supported by industry. Government-supported networks such as the network of centres of excellence would constitute an ideal framework for such university-industry-research institution partnerships, and would therefore contribute substantially to the industry's technological advancement and success. Government programs designed to encourage and facilitate technology upgrading or acquisition of market intelligence play a critical role, and they should be pursued. Tax incentives, research grants and other similar forms of assistance should continue to be available to foster innovation.

Responsibility: governments, industry

NETWORK

4. Create a science and technology network to support development of the breakthrough technologies identified in the program, and accelerate technology transfer

A high degree of collaboration already exists between the industry, its research institutions, universities, and equipment or service suppliers. This should be reinforced and expanded, especially with equipment manufacturers and engineering firms, because innovations issuing from laboratories frequently need to be demonstrated at pilot plant level, and integrated into existing or new machinery before industry can benefit from them. The network also needs to include specialists from non-traditional disciplines (computer science, mathematics, industrial engineering, materials science, polymer science, civil engineering, mechanical engineering, etc.) as well as economics, business and market experts.

A broad network of this nature would facilitate the adoption of a holistic but realistic approach to research and development, and guarantee success in the implementation of R&D programs firmly anchored in innovation, yet committed to market relevance and continuing profitability for the industry.

The Web represents an ideal tool for exchanges of information between network participants. A strategy should be developed to create dedicated Web sites providing information in best available technology, and to provide network participants with advanced tools (e.g., specialised search engines) to access relevant Web resources.

Responsibility: industry, research institutions, universities

5. Adopt advanced mechanisms for the collection of intelligence on market opportunities

Given the high priority assigned by the lumber industry to market diversification, value-added and niche marketing, the marketing tools traditionally used for commodities will no longer be sufficient. The industry requires market intelligence of the type more commonly associated with consumer goods, and modern market research methods that are borrowed from that sector to predict desirable product attributes on the basis of trends in economics, consumer preferences and government legislation. Advanced market intelligence is also essential to effective design development. All initiatives in this domain need to consider e-commerce and its potential for the Canadian wood industry.

A systematic search should be initiated for non-conventional applications which could be pursued by the industry and its research organisations (i.e., applications for which new products or systems could be developed and manufactured on the general basis of the industry's technology). One objective of this search for innovative applications should be to reduce intra-industry competition, reinforce the industry's position against competing building materials, and maximise penetration of new markets.

Responsibility: industry associations, research institutions, universities, governments

6. Provide market feedback to industry and research groups

There appears to be a need to better integrate market research, product and systems development, and the industry's marketing initiatives so that all stakeholders may push (and pull) in the same direction. The most efficient way to achieve such integration might be to extend the science and technology network described in Number 2 above to market research, and to obtain participation of industry's marketing experts on the advisory committees discussed in Number 3.

Responsibility: industry, industry associations, research institutions, universities, governments

7. Encourage the growth of Canadian equipment, software and service suppliers

It is obvious that, if the Canadian lumber industry is to be, and remain, a technology leader, its research institutions have to demonstrate technology leadership. It is equally obvious that it needs to be supported by suppliers who are, themselves, technology leaders. As new technology gets developed in this country, steps should be taken to ensure that: Canadian suppliers (or would-be suppliers) have a fair chance to turn R&D results into profitable business ventures; the Canadian lumber industry and its value-added sectors benefit by having priority access to innovative equipment, software or services; and Canada positions itself to become a major exporter of technology, equipment, software, and services.

Government and industry initiatives to facilitate the transfer of technology from the laboratory to the industrial stage (e.g., pilot plant demonstration) are very helpful in this regard, but they remain far too limited. Consideration should also be given to the development of clusters of complementary companies, which combine their skills to implement new technology, and pursue world markets.

Close relationships between industry suppliers, manufacturers and research scientists are essential, and, as suggested earlier, suppliers should form part of the network supporting the industry's research and development program.

Responsibility: industry suppliers, research institutions, industry, governments

MARKET ACCESS

8. Make active use of R&D results to support Canadian wood products and systems world wide, and eliminate discrimination against them

The Canadian lumber industry is largely dependent on exports, and future growth will mostly be predicated on increased demand from external markets. This is equally true of wood-based value-added products, and particularly engineered products and systems, which are specifically designed for structural applications. Any long-term marketing program therefore needs to include provisions for market access such as determined by national or regional codes and standards. By participating in the development of international standards (e.g., International Organisation for Standardisation [ISO], International Union of Testing and Research Laboratories for Materials & Structures [RILEM]), Canadian scientists get a chance to earn the respect of their peers for their research, and to shape standards in ways compatible with Canadian preferences. Occasionally, internationally prestigious scientists even receive invitations to contribute to the development of foreign national codes and standards.

The provision of scientific support to codes and standard development in Canada, in the US, Japan, China and other major or emerging markets needs to continue as a high priority activity in the R&D program of the Canadian lumber industry, and adequate funds need to be made available for this activity.

Responsibility: industry, industry associations, research institutions, governments

DESIGN FOR VALUE ENHANCEMENT

9. Encourage resource production and allocation for increased product value and sustainable development

In both the softwood and the hardwood sectors of the Canadian lumber industry, there is some degree of concern over future access to sufficient quantities of adequate wood supplies. In this context, government measures to allocate the resource, with priority given to those capable of converting it into the highest value products, seem likely to provide an extra incentive for technology-based growth, with related positive impact on quality employment in rural areas.

Over the longer-term, industry access to adequate wood supplies will be determined by today's forest management policies and practices. Results from research programs investigating relationships between silvicultural operations and future product characteristics will help foresters make the right decisions. This research, however, has only recently been receiving the attention it deserves, and the task ahead is enormous. Identification of relatively short-term benefits (e.g., thinning operations) may help convince the major stakeholders that additional investment in this domain could be warranted.

Research should continue on the wood characteristics of secondary wood species (e.g., larch, alder) to determine their suitability for value-added applications. Poplar and other species commonly used in plantations need to be investigated, so that foresters may select clones more likely to yield the desired wood properties.

The National Standard for Sustainable Forest Management represents another tool to ensure adequate wood supplies over the longer term, and companies relying directly on forest resources should be encouraged to seek certification under that standard.

Responsibility: governments, industry, research institutions

10. Encourage further manufacturing, and production of specialty and value-added products

Even if commodity lumber producers successfully diversify their production and create new lines of products to expand their markets, large plants will continue to be constrained in terms of flexibility and response time. However, the industry's efforts can be greatly amplified by a vibrant secondary manufacturing sector, capable of absorbing part of the primary production, and creating opportunities for added value, innovation and employment. Several government programs were recently initiated to support expansion of secondary manufacturing through research and the transfer of technology. Other programs provide assistance with market studies and business plans.

Given that secondary manufacturing companies tend to be small and isolated, they will not be in a position to support expensive R&D on an individual basis, and formulas should be devised to allow them continuing access to advanced R&D and technology transfer services on a permanent basis.

Responsibility: industry, industry associations, governments, research institutions

11. *Develop strategies to support Canadian use of design as a means of promoting wood utilisation*

Design is the most efficient vehicle to match market requirements and product specifications. It is true in the furniture industry and other similar sectors, where value, as seen by the end-user, is essentially determined by functional or aesthetic attributes of a finished product. As demonstrated many years ago by the example of Scandinavian and Italian furniture manufacturers, the development of design as the ultimate value-added instrument, and international recognition of Canadian design would give the Canadian appearance wood product industry a powerful tool to promote its products. Initiatives to this effect should be encouraged.

In the engineered wood product sector, with building construction as the dominant application, products are used as part of a system, and the performance characteristics of the system (e.g., architectural properties, fire resistance, durability, structural integrity, final cost) are far more important than those of its individual components. The most effective form of innovation involves the design of systems against desired performance criteria (i.e., market requirements), and the design of wood-based products best suited to these systems. As with appearance products, design has huge potential as a marketing tool for wood; it is also the most efficient approach to developing new engineered products matching resource characteristics and end-user expectations.

A major initiative is required to analyse factors involved in the design and production of building systems, especially for commercial building construction, and to develop strategies to position the wood industry as the leading supplier of advanced systems for low- and medium-rise construction.

Responsibility: industry, industry associations, government, research institutions, educational institutions

EDUCATION AND TRAINING

12. Pursue the reinforcement of ties between the industry, its research institutions, universities and colleges to attract more high-calibre students

The performance of the Canadian lumber industry's R&D programs and their implementation will require sets of skills (process control, computer science, industrial engineering, materials science, mathematics, business analysis, polymer chemistry, design, market research, etc.) which students may not immediately associate with the wood industry.

To change this, co-op programs need to be set up to encourage universities and colleges to offer programs adapted to the wood industry (beyond wood science), and to encourage industry to evaluate the potential benefits of hiring college and university graduates. Emphasis on advanced technology will also attract high-calibre students to research institutions and the supplying industries (e.g., equipment, software).

Because they specialise in applied research, the industry's R&D institutions should continue playing a key role as intermediaries between educational institutions and industry. They should also become more involved in joint projects to provide colleges with modern training facilities and tools.

Responsibility: universities and colleges, industry, research institutions

13. Reinforce training and re-training programs

The roadmap suggested in this report emphasises reliance on technology as the key to continuing industry prosperity. This conjures up images of advanced automation, and automation is undeniably part of the plan, but even automated plants need people to operate them, and the rapid introduction of a technology culture requires support from employees and management. To foster positive attitudes to technology, industry should develop programs involving employees in technological advancement (e.g., team building, employee support, empowerment, and innovation incentives). Training and upgrading courses for the acquisition of skills in computerised process control, process simulation, etc., should be offered through apprenticeship programs or other forms of certification.

Training and the adoption of positive attitudes to new technology will be facilitated by the development of computer-based tools which can be used to simulate processes; test the impact of various decisions on cost, quality, etc.; and demonstrate the benefits of specific innovations.

Strategies should be developed to use the Web as a vehicle for the transfer of educational material, in addition to CD-ROMs, videos and teleconferencing.

Partnerships should facilitate the development of decision-aid and expert systems as needed to meet the technology requirements of smaller producers, particularly those in the value-added sectors.

Finally, training and education will only be effective if educators themselves remain state-of-the-art. The wood industry's research institutions and trade associations can play a key role in transferring technology to educational institutions with an emphasis on updating the knowledge of the educators.

Responsibilities:industry, research institutions, colleges, industry associations

14. Encourage transfer of state-of-the-art technology to specifiers and end-users

New product attributes will not provide marketing benefits or serve the industry's goals if they are not efficiently communicated by industry to decision-makers and the public at large. This has been part of the trade associations' mandate, and they will require expanded resources as product lines diversify, and product characteristics become more complex.

Consensus codes and standards committees are typically forums where manufacturers, end-users and scientists work together. They constitute good opportunities for mutual education, and participation by industry and research staff should be firmly encouraged.

Involvement of some categories of specifiers and end-users in the proposed network will also help keep them up-to-date on new developments, at the same time as it gives them an opportunity to receive feed-back.

Responsibility: industry, industry associations, research institutions

In Conclusion...

One objective of this report was to encourage discussion within the Canadian lumber industry, including its fast moving secondary manufacturing sector, its suppliers, its research institutions, its trade associations, universities, and governments. The process followed in the preparation of the report has already created increased awareness of issues affecting the future of the industry. This roadmap should be used as a base for continuing discussions and for the development of a consensus for action plans on national, regional and sectoral bases.

This report should also become a living document to be used by all stakeholders as a means of monitoring progress, adjusting objectives, and defining new goals.